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THE
EXHIBITED MACHINERY
 OF
1862:

A CYCLOPÆDIA OF THE MACHINERY REPRESENTED
 AT THE INTERNATIONAL EXHIBITION.

BY
David Kinnear
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 INTERNATIONAL EXHIBITION, 1862; AUTHOR OF "RAILWAY MACHINERY;" ETC.

DAY & SON,
 LITHOGRAPHERS TO THE QUEEN AND TO H.R.H THE PRINCE OF WALES,
 GATE STREET, LINCOLN'S INN FIELDS,
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TO
WILLIAM FAIRBAIRN, ESQ. C.E.

LL.D. F.R.S. F.G.S. ETC. ETC.

This Work
ON
THE EXHIBITED MACHINERY OF 1862,

Is Dedicated

AS A TRIBUTE OF RESPECT AND ESTEEM,

BY
THE AUTHOR.

P R E F A C E.

THIS book has been written for the purpose of supplying a descriptive and critical analysis of the Machinery exhibited at South Kensington in 1862. The descriptive particulars are, for the most part, based upon the observations of the Author, who, as Superintendent of the Machinery Department, had frequent opportunities of examining the machinery. In addition, he has availed himself of the co-operation of Exhibitors in verifying and authenticating the descriptive matter of this Work, to whom, in the majority of instances, proofs have for that purpose been submitted. These gentlemen have willingly responded to the Author's applications, and he embraces this opportunity of acknowledging their courtesy. Upwards of eleven hundred machines and portions of machines have thus been accurately noticed, or described in detail: constituting a compact Cyclopædia of Machinery, valuable as a text-book for students, and as a work of reference for engineers.

In the arrangement of this Work, the Author has, in general, followed the classification of machinery adopted by Her Majesty's Commissioners for the International Exhibition, and comprehended in the Official Industrial Catalogue.

Part I., on Railway Plant, embraces the contents of what has been known as Class 5.

Part II., on the Machinery for Manufacturing Textile Fabrics, embodies the contents of Class 7*a*.

Part III., on the Manufacturing Machines and Tools for Working in Iron, Wood, and other Materials, relates to the contents of Class 7*b*.

Part IV., on Machinery in General, to the contents of Class 8.

With every disposition to compress the matter of this volume within smaller limits, it has, nevertheless, been extended to nearly one half more than the space originally assigned for it; as it was found that those limits could not be observed without injuriously curtailing the book. In fact, the volume might easily and profitably have been extended to double the size.

Though the Author does not hope to satisfy everybody, he has endeavoured, to the best of his ability, to do honour where honour is due; and, whilst he has avoided needless commentary, he has given prominence to the more remarkable works exhibited, in defining the course of improvement.

The Woodcuts and Plate-engravings will be found of great utility in illustrating the text. The Plan of the Western Annex shows the arrangement of the Machinery Department, as prepared and carried out by the Author for Her Majesty's Commissioners: it will possess considerable interest, particularly for those who were identified or associated with that Department. The drawing from which the plan has been reduced, was carefully made for the Author by Mr. John Cundy, Deputy-superintendent of the Annex. A number of machines were drafted to the Eastern Annex, for want of space in the Western, which accounts for the absence of those machines from the plan.

Whilst the arrangements for unloading the machinery on its arrival, and for delivering it at the Western Annex, were ably matured by Mr. R. A. Thompson, the system of distributing and delivering the goods at the respective stations within the Annex, by the agency of steam-power, was organized by the Author. For these objects, lines of rails were laid down in the main thoroughfares, on which the machinery was conveyed upon trucks to every part of the Annex. Special acknowledgments are due to Messrs. Manning, Wardle, & Co. for their permission to employ the tank-locomotive, sent by them for exhibition, in moving the trucks; to Messrs. Alexander Chaplin & Co. for the free service of a couple of their portable steam-cranes within the Annex; to Messrs. Bowser & Cameron for the free use of their moveable derrick-crane; and to Messrs. Thomas Dunn & Co. for the use of their surface-turntables and engine-traversers. In speaking of the use of steam-power, it may be added that Bray's traction-engine was busily and successfully at work in conveying the heavy machinery from the docks and the railway termini to the Exhibition.

D. K. CLARK.

11, ADAM STREET, ADELPHI, LONDON, W.C.

March 31, 1864.

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ERRATA, &c.

- Table, page 10, London and North-Western Railway Company's Locomotive, correct the "area of grate" from 25 to 26.
- Table, page 10, insert at Locomotive by Beyer, Peacock, & Co.,—"Weight of Engine in Working Order:—At leading wheels, 9 tons 4 cwt.; at middle wheels, 11 tons 12 cwt.; at trailing wheels, 7 tons 10 cwt.; total weight, 28 tons 6 cwt.
- Table, page 10, correct "The Weight of Engine Empty," thus:—At leading wheels, 8 tons 10 cwt.; at middle wheels, 10 tons 14 cwt.; at trailing wheels, 6 tons 6 cwt.; total weight, 25 tons 10 cwt.
- Table, page 10, "Locomotive by Wm. Fairbairn & Sons," correct the total heating surface to 1,160 square feet.
- Table, page 10, "Locomotive by G. England & Co.," correct the working pressure in boiler to 120 lb.
- Page 32, column 2, line 11 from foot, for "Thomas" read "John."
- Page 202, column 1, line 16 from foot, for "single-acting" read "double-acting."
- Page 266, column 1, line 11 from foot, for "Hulot" read "Halot."
- Page 275, head-line, for "T." read "F."
- „ Fig. 257, for "T." read "F."
- Page 276, column 1, line 10 from foot, for "T." read "F."
- Page 324, column 2, line 29, for "steam" read "scam."
- Page 432, column 4, line 3 from foot, for "Coombe" read "Combe."

I.—RAILWAY PLANT.

CHAPTER I.

INTRODUCTION.

MORE than two hundred years ago, Master Beaumont, "a gentleman of great ingenuity and rare parts, adventured into our mines [near Newcastle] with his £30,000, who brought with him many rare engines not known then in those parts, as the art to boore with iron rods, to try the deepnease and thicknesse of the coale; rare engines to draw water out of the pits; waggons with one horse to carry down coales from the pits to the staythes on the river, etc. Within a few years he consumed all his money, and rode home upon his light horse." This was probably at the beginning of railways, the experimental stage, when capital was sunk, individuals ruined, and the public benefited. In 1676, railways consisted of rails of timber, exactly straight and parallel, and bulky carts were made, with four rollers fitting the rails, "whereby the carriage was so easy, that one horse would draw down four or five chaldron of coals, and was immense benefit to the coal merchants." At that time, the railways had become remunerative, and proved themselves to be legitimate speculations.

A hundred years later,—about one hundred years ago,—cast-iron wheels, and subsequently cast-iron rails, were introduced; and about fifty years ago, wrought-iron rails were laid down in lieu of cast-iron. About the same time, steam locomotives on railways were introduced by Mr. Trevithick, to supersede horse-power; and the inventiveness of the father cropped out at the Great Exhibition of 1851, in the conspicuous "Cornwall" locomotive, designed and exhibited by his eldest son. In 1814, Mr. George Stephenson constructed his first locomotive; and the year 1829 was made famous in the annals of railways for two things:—the opening of the Liverpool and Manchester Railway, the type and forerunner of modern railways; and the invention and construction of the first high-speed locomotive of the standard modern type:—the railway and the locomotive by Mr. Stephenson and his son, Mr. Robert Stephenson. This engine, the "Rocket," weighed 4 tons 5 cwt.; its tender, 3 tons 4 cwt. It comprised the three elements of efficiency of the modern locomotive:

the internal water-surrounded fire-box, and the multitubular flue in the boiler, being a number of small tubes in place of one large tube; the blast-pipe, from which the waste steam of the engine was exhausted up the chimney; and the direct connection of the steam cylinders, two in number, one on each side of the engine, with the driving or propelling wheels on one axle. The key-note was struck; constructors on all sides worked each in his own way at the locomotive, to improve the details and increase the efficiency, and for many years the practice of builders was moulded into two general classes of engines,—with two cylinders placed horizontally inside the smoke-box under the chimney, and otherwise essentially similar to each other, except in one great feature—the number and disposition of the wheels—some having six wheels, others four. Eventually, six wheels were applied to all ordinary locomotive stock. Scarcely had the wheel controversy been settled, when the system of outside cylinders with straight axles was re-introduced, as opposed to the system of inside cylinders with cranked axles, each with its special characteristics; outside cylinders afforded additional facilities for increasing the power and convenience of the engines on narrow-gauge railways, in order to compete with the inside-cylinder engine, retained on the broad gauge; but the unsteadiness, unsafe at high speeds, induced by the external and wide-spread reciprocating masses in the outside system, was found to be a serious objection to its adoption and extension. Mr. Crampton, then, in 1843, solved the problem for passenger locomotives, to obtain power, speed, and stability in all its fulness,—combining a low centre of gravity with outside cylinders, a large driving-wheel, and a powerful boiler. The reciprocating masses spent their action upon the driving-axle, which was placed at the end of the engine, behind the fire-box, and were for the most part deprived of the power of swaying the machine. The most powerful engine of this class, the "Liverpool," weighing 35 tons, the *ultimatum* of power for the narrow gauge, was exhibited in 1851, alongside its magnificent rival, the "Lord of the Isles," passenger locomotive on the broad gauge, also weighing 35 tons.

It had, nevertheless, been discovered that the

objectionable unsteadiness of ordinary outside-cylinder engines could be partially remedied by the application of counterweights in the driving wheels, so proportioned as to balance the revolving portions of the machinery; and that, in fact, it could be advantageously employed also with inside cylinders. In 1845 Mr. Fernihough found that the whole of the reciprocating, as well as the revolving, masses could be balanced by a weight in the wheel; but his results do not appear to have been generally appreciated. In 1852, the Author first publicly investigated and advocated in this country this system of balancing engines;* and he adopted it in the locomotives designed by him for the Great North of Scotland Railway, in 1853, with the most satisfactory results, operating as a perfect corrective of unsteadiness by internal disturbance, at all speeds. This system of balancing is now almost universally adopted for both outside and inside cylinders; and that baneful element of instability having been eliminated, outside cylinders have grown into more general favour, and the result has been a decided preponderance of outside cylinders over inside cylinders at the International Exhibition of 1862.

The best and most recent practice of locomotives, particularly in the United Kingdom, was fairly exhibited in 1862. But in variety, boldness, and originality of design, English exhibitors were surpassed by their continental neighbours. Twenty locomotives were exhibited, of which eleven were sent from the United Kingdom, three from France, one from Belgium, two from Austria, one from Prussia, one from Saxony, and one from Italy. Fourteen locomotives had outside cylinders, and six had inside cylinders. In seven of the English engines the cylinders were outside, in four they were inside. Most of them were specially constructed for burning coal—a specialty which has been introduced entirely since 1851, on account of the less cost of coal for fuel, as compared with coke.

CHAPTER II.

HISTORICAL ACCOUNT OF COAL-BURNING IN LOCOMOTIVES.

The physical conditions of the complete combustion of coal are,—first, that the introduction of air should be in sufficient quantity, and suitably distributed amongst the solid and gaseous portions of the fuel in the furnace, altogether or partially, through the grate, and partially above the fuel, directly to the gases; secondly, that the temperature should be maintained suffi-

ciently high within the furnace, so that it should not be lowered by external causes, during the combustion of the hydro-carbon gases, in order to effect the union of the element of carbon with its full proportion of oxygen; and thirdly, that the combustible gases should be thoroughly mixed with their supply of air.

With the limited fire-box of a common locomotive boiler to deal with, enginemen have had recourse to various ways of treating the fire, in order to diminish the nuisance of smoke. They have relied chiefly on the instrumentality of the ash-pan, the dampers, and the fire-door, for carrying out a system of careful firing. They have endeavoured to prevent the formation of smoke by controlling the admission of air through the grate, and adjusting it precisely to the requirements of the fuel; by similarly manœuvring the fire-door for the admission of air above the fuel; by stoking with large pieces of coal and deep fires for heavy duty, and smaller coal with shallow fires for lighter duty; by firing more frequently, to lighten the duty; and at all times, by keeping the bars covered with fuel, to prevent excessive local draughts through the grate. That much may be effected by these means, there is no doubt. It is well understood that the nuisance of smoke on entering or waiting at stations may be very much, or in some cases even altogether, subdued, by thoroughly closing the ash-pan, and by opening wide the fire-door.

Low-pitched doorways at the level of the fuel introduce fresh air to greater advantage than those which are set high, as the air through the low door mixes more quickly and more freely with the gases as they rise. It was, accordingly, found advantageous to adopt the practice of charging the fresh coal chiefly under the fire-door upon the hind part of the grate, and subsequently, when relieved of its gaseous element, pushing it forward towards the tubes, thus making way for a succeeding charge behind. Such have been the usual modes of treating coal, as fuel, in locomotive boilers of the normal type, in their normal condition. But the elaborations of practice in stoking ordinary boilers have been to a considerable extent superseded, within the last few years, by the methods, recently introduced, of admitting air above the fuel, near its surface, and amongst the combustible gases. These methods may be classed as acting—first, by currents of air introduced through tubular or other openings in the sides of the fire-box, uniformly distributed over the surface of the fuel; and secondly, by the deflection of a body of air introduced through the doorway, upon and over the surface of the fuel. A different principle of operation has also been introduced, by constructing large and spacious fire-boxes, with large grates and long runs.

The three leading classes of coal-burning boilers, thus indicated, are variously represented, in chronological order, by the annexed diagrams; and, first, the adaptation of large ex-

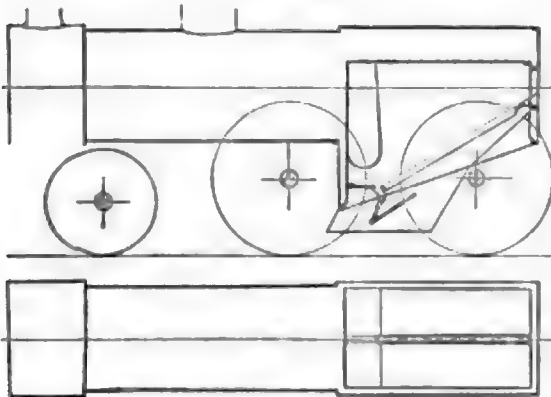
* See "Railway Machinery," by D. K. Clark, — Blackie & Son,—in which the author has fully investigated the causes of, and remedies for, instability in locomotives.

tended fire-boxes and combustion-chambers, by Mr. M'Connell, in 1853 (fig. 1); by Mr. Beattie, in 1855 (fig. 2); and by Mr. Cudworth, in 1857 (fig. 3).

In Mr. M'Connell's plan there is a large grate, a long run, and air-tubes through the front and sides; and the system provides the greatest practicable area of fire-grate, in order that the coal may burn with moderate intensity and free from clinker, and that plenty of air may pass into the fire-box, through the grate, to consume the gases. The combustion is assisted by the introduction of air through the front and sides of the fire-box; and a large capacity and length of run are provided by adding a combustion-chamber, which is simply an extension of the fire-box into the barrel of the boiler. To provide for alternate firing, the fire-box is divided longitudinally into two compartments. This plan, with good management and the use of a steam-jet in the chimney when the engine is at rest, is tolerably effective in preventing smoke.

In Mr. Beattie's boiler, as in Mr. M'Connell's, the grate is large, and the run is divided and extended by the addition of a combustion-chamber projected into the barrel, with brick arches and tiles. The fire-box is divided transversely into two compartments by an inclined water-space diaphragm. Both compartments are arched over with fire-tiles at narrow intervals; the combustion-chamber also is stocked with perforated bricks or curved tiles, placed at some distance clear of the tubes. The fire-tiles receive and retain a portion of the heat from the passing gases when the fuel is incandescent and smokeless, and restore it to the smoke passing from

FIG. 3.

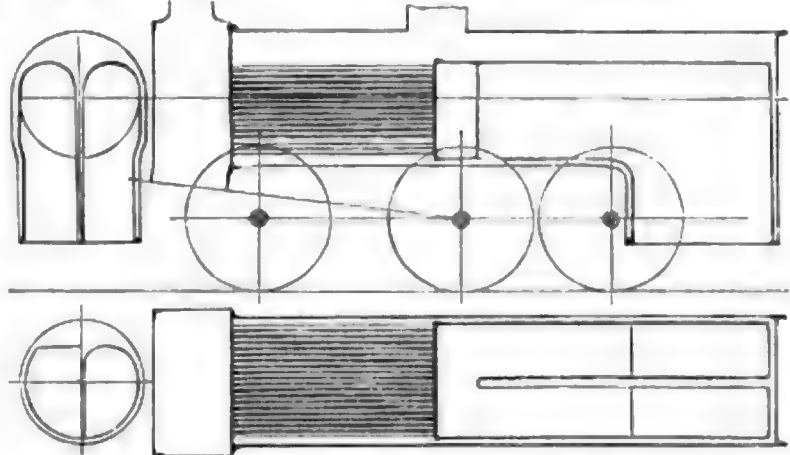


COAL-BURNING LOCOMOTIVE, by Mr. J. Cudworth, 1857; with inclined grate, and fire-box divided longitudinally for alternate firing.

fresh coal; thus acting as equalizers of temperature. The tiles also break up and mix the gases

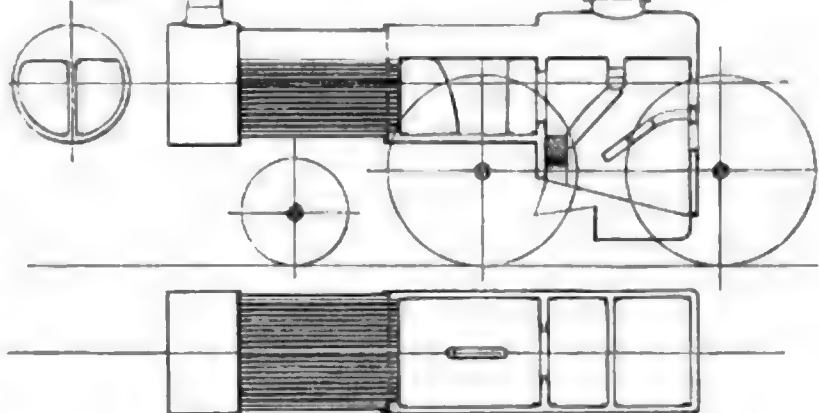
and air; and partly by mixing, and, it is supposed, partly by heating, they promote combustion. The first furnace is the most actively worked; the second is chiefly designed to carry

FIG. 1.



COAL-BURNING LOCOMOTIVE, by Mr. J. E. M'Connell, 1853; with the fire-box divided longitudinally by a midfeather and combustion-chamber, for alternate firing.

FIG. 2.



COAL-BURNING LOCOMOTIVE, by Mr. J. Beattie, 1855; with fire-brick arches, and combustion-chamber filled with fire-tiles.

by small apertures, and similarly through the back of the fire-box by slides. The gases from the first and principal furnace pass through the tile bridge, are deflected by the hanging transverse diaphragm towards the hot fire in the second furnace, and then pass through the second tile bridge and the mass of tiles in the combustion-chamber before they enter the tubes. The object of this invention is to equalise the temperature of the gases, to prepare the colder gases for ignition, under all fluctuations of temperature, and also to perfect the mixture of the gases and air, in order to effect their entire combustion. An auxiliary steam-jet is opened into the chimney when the blast is off, to stimulate the draught, and to prevent smoke. This plan works very well.

Mr. Cudworth's plan combines an inclined grate with a long run. The incandescent fuel slides forward, and the fresh coal is charged near the doorway. The fire-box is divided by a lon-

gitudinal diaphragm into two compartments, making two furnaces, which unite in front of the tube-plate. With the aid of an auxiliary jet in the chimney, Mr. Cudworth's plan may be made tolerably effectual in preventing smoke.

But it was necessary to adapt the existing engines, as they were, for burning coal without smoke by simple means, and independently of extensive structural alterations. This had been attempted by Messrs. Gray & Chanter in 1837, and again in 1839. They divided the fire-box into two compartments, one for coal and the other for coke; they also admitted air in streams through tubes in the walls of the fire-box, and they were the first who applied a steam-jet in the chimney, when the blast was off, to maintain a draught. Mr. Dewrance, in 1845, divided the fire-box into two parts—the furnace and combustion-chamber. Messrs. Dubs & Douglas, in 1856, constructed a deflecting mid-feather, proceeding from the back of the fire-box towards the tube-plate, to throw down the smoke over the incandescent fuel; and Messrs. Evans & Dubs, in 1857, added to this a movable inclined grate, capable of being raised or lowered for the management of the fire. After various attempts, Mr. Yarrow, in 1857, projected an arch of brick from the tube-plate towards the fire-door, and admitted air through tubes in the tube-plate under the arch, and through the fire-door, to mix with the smoke.

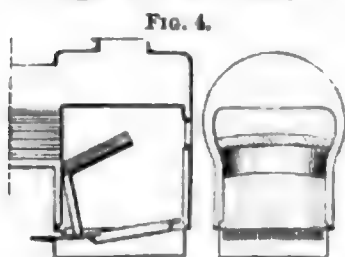


FIG. 4.
COAL-BURNING BOILER, by Mr. T. Yarrow, 1857; with fire-brick arch and air-bars.

He subsequently superseded the air-tubes by upright air-bars near the tube-plate (fig. 4). In the same year, Mr. Jenkins, admitting air through numerous air-tubes in the tube-plate, applied a curved partition across the fire-box to throw forward the air, distributing it through numerous small holes at the upper part. He regulated the supply of air by a damper, and more recently he added a row of air-tubes under the fire-door (fig. 5).

Towards the end of 1857, the Author, believing that a simple means of increasing the supply of air, and forcibly distributing and mixing it with the smoke in a common open fire-box, independently of internal appliances, was a desideratum, devised his system of steam-induced air-currents, in which, in its simplest form, air-currents are admitted

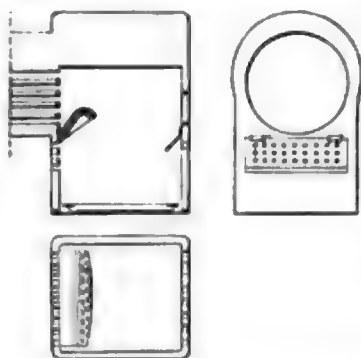


FIG. 5.
COAL-BURNING BOILER, by Mr. Jenkins, 1857; with air-tubes and arched deflector.

just above the fuel, by tubes or otherwise, through the sides of the fire-box, and are forcibly accelerated by means of jets of steam directed from the outside through the openings into and across the fire-box; the steam-nozzles operating through the air-tubes, as the blast does in the chimney. In December, 1857, the Author applied his system to one side of a small stationary locomotive boiler at the railway foundry, New Cross. There were two air-tubes, and a jet of steam to each tube, from small nozzles on the outside, 1-16th of an inch in diameter, to increase the quantity and velocity of the air introduced. This simple apparatus was for several months in operation, and the dark smoke which was discharged when it was not in action was entirely prevented by its use. In January, 1858, a tank-engine on the North London Railway was fitted with four air-tubes, 1½ inch in diameter, through one side only, the other being inaccessible; with the assistance of jets of steam of 1-16th of an inch, smoke was completely prevented when the surface of the fuel was below the level of the air-tubes. In April, 1858, a passenger engine on the Eastern Counties Railway was fitted with a row of air-tubes on each side,—four on one side, and three on the other,—with steam nozzles, one to each air-tube. With this application, the engine worked the main-line trains for eight or nine months, and the smoke was in general effectually prevented. In January, 1859, a passenger engine on the South Eastern Railway was fitted and put to work with two rows of air-tubes through the front and back walls of the fire-box, seven in each row, or fourteen in all, with induction-nozzles to every tube. On the Great North of Scotland Railway an engine was fitted on the Author's system with front and back air-tubes, under the direction of Mr. Cowan, the locomotive superintendent, and was started in March, 1859. The results have been in all respects satisfactory, and the same system has been applied by the superintendent to the entire locomotive stock of that railway. Fig. 6 shows its application to the goods engines. In 1859, one of the old passenger engines of the London and Brighton Railway was fitted with the Author's apparatus, a row of air-tubes, and induction-jets in the front only. Accidental circumstances rendered impracticable the insertion of air-tubes in the back. Smoke was effectually prevented, except when heavy charges of coal were delivered at once.

On the Great Western Railway, coal-smoke

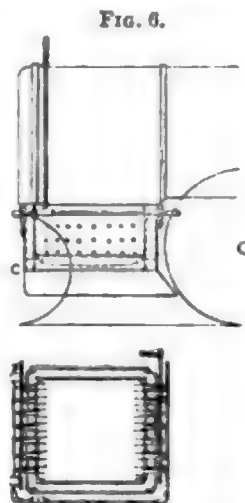
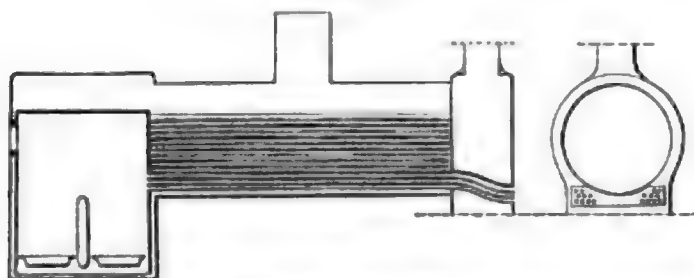


FIG. 6.
COAL-BURNING FIRE-BOX, by D. K. Clark, 1857-59; with air-tubes and induction steam-jets.

has been burned by admitting air into the fire-box over the fuel by numerous air-tubes, regulated by slides, through the front, sides, and back. On the Oxford, Worcester, and Wolverhampton Railway, a system was introduced by Mr. Edward Wilson, in 1858, in which air is conducted from the front of the smoke-box, through several of the lower flue-tubes, into the fire-box (fig. 7). On the Northern Division

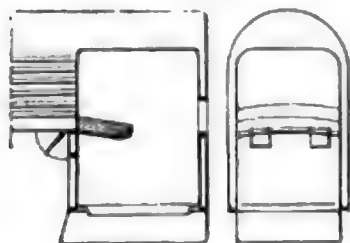
FIG. 7.



COAL-BURNING BOILER, by Mr. E. Wilson, 1858; with air-tubes through the boiler.

of the London and North-Western Railway, Mr. Ramsbottom, in 1859, introduced air under a brick arch by two openings, seven inches square, through the front of the fire-box (fig. 8).

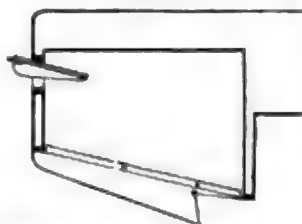
FIG. 8.



COAL-BURNING FIRE-BOX, by Mr. J. Ramsbottom, 1859; with fire-brick arch and two square air-openings.

With respect to the class of contrivances, acting by deflection, the initiative appears to have been taken on the Birkenhead Railway by Mr. Douglas, who, in January, 1858, applied a deflecting plate, fixed to the inner side of the door, through openings in which air was admitted, whence the air passed, and was deflected towards the fuel. In June, 1858, on the same line, a movable deflecting-plate, and an under-hung door, with a sector, and notches to regulate the opening for air, was applied, and more recently a plain inverted scoop or shovel (fig. 9). In July, 1858, on the East Lancashire Railway, Messrs. Lees & Jacques fixed the deflector to the door, which was under-hung, and was provided with a valve, the opening of which was regulated by a sector. They built in addition a narrow brick arch against the tube-plate, so that the smoke and air might, by their combined action, be better intermixed (fig. 10). In December, 1858, Mr. Sinclair, on the Eastern Counties Railway, applied a baffle plate inside the fire-box, hung over the doorway, and an under-hung door

FIG. 9.



COAL-BURNING FIRE-BOX, by Mr. Douglas, 1858; with inclined grate and doorway deflector.

regulated by notches, with two steam-roses, one on each side of the fire-box, to project steam downwards upon the fuel when the blast was off. This system was introduced by Mr. Frodsham (fig. 11). In 1858-9, an inverted shovel or scoop, similar to Mr. Douglas's, but longer, was, and has since been, extensively introduced, being placed in the doorway, and inclined towards the centre of the fire, in order to deliver the air directly on the top of the fuel.

It has not been attempted in the foregoing notices to describe all the plans that have been designed for the purpose of consuming coal without smoke in locomotives; the intention has been to show generally the directions in which engineers have operated for the means of insuring complete

combustion. There is one feature of considerable importance which is common to all—the steam blowpipe, or auxiliary jet, in the chimney.

This is made use of for the purpose of continuing the draught of the furnace when the powerful artificial stimulus of the blast is at intervals suspended.

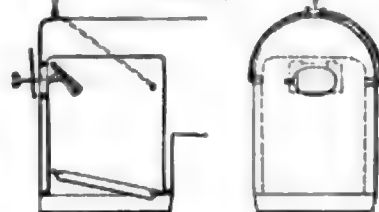
The necessity for admitting a supply of air above the fuel is understood and acknowledged by all, whether it is introduced through the grate or otherwise. When the grate is very large, and a thin fire is maintained, the supply of air may be taken almost entirely through the grate. It is, however, indispensable to this mode of managing the fire, that the fuel should be carefully supplied at short intervals, and in small quantities, uniformly distributed: in recognition of the principle, that the more nearly uniform the supply of fuel, the more so is the generation of combustible gases, and the more probable, accordingly, is the combustion of these gases and the prevention of smoke. With inclined grates, of course, the fuel is only deposited near the entrance, and it finds its way down by gravitation; and their greater ease of management in this respect, notwithstanding the frequent stoking they require compared with ordinary level grates, mainly constitutes their superiority. With small or moderate-sized level grates, a coal-fire demands still greater care than with larger grates, where smoke is to be prevented by air from the grate. The firing must be still more frequent, and as the door, of course, is more frequently opened, another evil is incurred—the admission of a large proportion of

FIG. 10.



COAL-BURNING FIRE-BOX, by Messrs. Lees and Jacques, 1858; with a brick arch and doorway deflector.

FIG. 11.



COAL-BURNING FIRE-BOX, by Mr. D. Frodsham, 1859; with doorway deflector and steam-roses at sides.

cold air into the fire-box, most of which passes off unburnt through the tubes, chilling the boiler, and checking the production of steam. Such evils are much reduced in magnitude by the simple process of admitting fresh air for the combustion of the gases otherwise than through the fuel, in greater or less proportions, according as it may be utilised; and as this independent admission of air is a very simple process, there can be no reason for endeavouring to dispense with it. Length of run promotes the mixture of air and gases; and in Mr. Beattie's boiler the mixture is further advanced by the interposition of fire tiles. The brick arch in the common fire-box operates beneficially in the same way, doubling the run and promoting the mixture. The baffle-plate, the hood, and the scoop, operate reversely, and with considerable success, by inverting the draught of the air admitted through the doorway, and directing it over the surface of the fuel. The baffle-plate is objectionable in inducing by its action the suction of particles of coal through the flue-tubes, and the burning of the smoke-box, unless counteracted by an internal brick arch; and the system requires a powerful blowpipe in the chimney. To insure the prompt and effective mixture of the air and gases, the air should be admitted and distributed at the surface of the fuel. But the ample admission and intimate intermixture of air with the gases above the fuel must be effected in conjunction with a sufficiently high temperature; and this condition has led to the adoption of various modes of heating the air or the gases, or both, prior to, or at the time of mixture. Mr. McConnell suggested the use of an air-chamber within the smoke-box, in which air was designed to be heated, and led into the fire-box through tubes. Mr. Wilson conducts air from the front through the smoke-box and the boiler by a number of the flue-tubes, and these also partially heat the air on its way to the fire-box, cooling the water in a proportionate degree. Mr. John Gray established a coke fire on a supplementary grate, as a reservoir of heat within the fire-chamber; and Mr. Beattie embodies his reservoir in masses of fire-brick. Others attempt to heat the air by conducting it partially over the surface of the fire-box shell. Expedients of this class operate in some degree advantageously; but in the adoption of such supplementary contrivances, it appears to have been overlooked that there is abundance of heat within the incandescent fuel itself to supply the demand for temperature. The problem appears to resolve itself into the immediate and thorough intermixture of a plentiful but regulated supply of air with the ascending smoke or combustible gases, at or near to the surface of fuel. Practically, it is found necessary for this object to operate from both the front and the back of the fire-box; admitting air, or using arches, deflectors, or bafflers, or doing both, as has already been described. But these contrivances, which deal with air in

bulk, though generally effective in preventing smoke, are usually attended by the escape of a considerable quantity of unconsumed air through the flue-tubes, and a difficulty, in many cases, in keeping up the steam at high speeds. The various forms of doorway deflectors are also objectionable, as previously stated, facilitating by their mode of action the suction of particles of coal through the tubes, and the burning of the smoke-box, unless counteracted by an internal arch. The Author has found, by experience, that to burn smoke when the engine is running, it is sufficient that the air should be admitted at or near the surface of the fuel, by air-tubes distributed over the width of the fire-box in the front and the back, without the aid of internal arches or deflectors. The draughts of air, through the front tubes particularly, are very strong when the engine runs ahead, and they carry the currents into the middle of the fire-box, where they meet the counter-currents from the back, effect the mixture of the air and smoke, and prevent the suction of small coal through the tubes. But in all systems applied to ordinary fire-boxes, operating by means of the draught available in a locomotive engine, aided, when the blast is off, by the steam-jet in the chimney, range of power is wanting to overtake the extremes of intense ignition and rapid generation of smoke-making gases, immediately after the steam is shut off, or when fresh fuel is added; and also to suit itself to the quiet state of the fire when the glow and excitement subside, as well as to all the varying conditions of a locomotive furnace. The means of extending the range, volume, and power of the air-currents, and of adjusting them to the wants of the furnace, are supplied by the instrumentality of the jets of steam employed by the Author as a means of inducting and accelerating currents of air. The steam nozzles, with the air-tubes towards which they are pointed, are like so many miniature blast-pipes and chimneys turned into the fire-box; and they possess, relatively, the same power of urging and creating draught. By this method of steam induction, the air-currents are delivered with such precision and velocity as to sweep the whole surface of the fuel, and forcibly to distribute the air amongst the gases. Of the virtue of forcible impingement in promoting and accelerating combustion, numerous examples occur in ordinary practice. It is in virtue of this principle that the ordinary bellows accelerate ignition; and if the upper front of a fire-place is closed with a sheet of paper, to direct the draught through the bars upon the fuel and combustible gases, the air-currents so deflected and forcibly directed upon them consume the gases and prevent smoke. The contracted neck of the glass tube of a moderator lamp, adjusted so as to direct the ascending air within the tube upon the upper part of the flame, increases its volume and brightness. In Mr. Beattie's boiler, the smoke-

consuming process is, to a great extent, based on the same principle of forcible mingling of the air and gases amongst each other, as they roll against the fire-tiles and diaphragms. By the Author's process, the entire operation is consummated within the four walls of an ordinary fire-box, the inducted currents sweeping up the gases and forcibly intermixing with them.

In comparing the merits and performances of various methods of coal-burning without smoke, there is the difficulty of diversity of circumstances to contend with, as to weather, fuel, engine, and duty. The Author read a paper before the Institution of Civil Engineers, in May, 1860, containing the results of his observations on coal-burning in locomotive engines during the period from 1854 to 1860, from which he abstracts the following particulars, and to which he may refer the reader for fuller details. Of the three systems of extended fire-boxes by Mr. M'Connell, Mr. Beattie, and Mr. Cudworth, it appears that with nearly equal gross weights,—102 tons to 116 tons of engine, tender, and train,—and at nearly equal speeds, Mr. M'Connell's system consumed $35\frac{1}{2}$ lb. of coal per mile, Mr. Beattie's 24 lb. (the feedwater heater being shut off), and Mr. Cudworth's 26 lb.; or, per ton gross, Mr. M'Connell's system consumed 0.31 lb., Mr. Beattie's 0.235 lb., and Mr. Cudworth's 0.225 lb. The evaporative powers rank in the same order—i.e., Mr. M'Connell's evaporated 5.9 lb. of water per lb. of coal, Mr. Beattie's 8.31 lb., and Mr. Cudworth's 8.6 lb. The excellence of Mr. Beattie's and Mr. Cudworth's systems is to be ascribed to the proximity of the radiant-heating surface to the fuel and the flame; in both systems the steam is well kept up.

Comparing coke with coal on similar duty, whilst Mr. M'Connell used one-half more coal than coke, Mr. Cudworth employed upon the whole rather less coal than coke, the general average being 27.3 lb. of coke against 25.8 lb. of coking coal per mile, or $5\frac{1}{2}$ per cent. less coal than coke. But he found that coking coal ranks higher in evaporating power than other coals he has tried—Lord Ward's coal and Ruabon coal—of which the consumption would be greater than that of coke.

Of the systems of coal-burning engrafted on the common fire-box, Mr. Yarrow's consumed 26.8 lb. of Scotch coal against 22.1 lb. of coke per mile on the same duty, showing an excess of 4.7 lb., or 21 per cent. more coal than coke. Mr. Jenkins used 30.35 lb. of coal against 32.43 lb. of coke, or 6 per cent. less coal, on the Lancashire and Yorkshire Railway. When tried on the Brighton Railway, his system used about 23 per cent. more coal than coke. Mr. Lee's system, on the same line, used about 20 per cent. more coal; and the Author's system, on the same line and on the same engine as that upon which Mr. Jenkins's plan

was tried, used about $7\frac{1}{2}$ per cent. more coal than coke.

On the Eastern Counties line the Author's system, working against a strong wind, used 11 per cent. more coal than coke, working in a calm; and on the North London Railway the same weight of coal as of coke was used—viz, 26 lb. per mile.

On the South Eastern Railway, by the Author's system, 14.4 lb. of coking coal were used against 16.28 lb. of coke per mile in a similar engine, on the same duty, for twelve months, showing a consumption of $11\frac{1}{2}$ per cent. less coal than coke. On the Great North of Scotland line there has not been an opportunity of trying coke against coal for long periods, as coal has for several years been largely consumed along with coke on that line. But Engine No. 5 was put upon trial for several weeks, burning English coke alone against different kinds of Scotch coal. The trains, as well as the weather, were variable; but, under similar circumstances, 9 per cent. less coal than coke was consumed per ton of the gross moved weight of the train. At the same time, whilst $8\frac{3}{8}$ lb. of water appeared to be evaporated per pound of coke, the water raised per pound of coal averaged only 8 lb. Thus, with a lower evaporative duty, there was a higher working duty with coal than with coke. This may be ascribed probably to the great command of steam afforded by the use of coal in these engines.

In comparing the coal-burning practice on different lines, the inferior strength of Scotch coal to that of English coke and coal is to be borne in mind. The frequency of the stoppages is another element, as every stoppage of a passenger train, under ordinary circumstances, occasions a delay of from three minutes to five minutes as compared with a through-running train. The table (page 8) contains a selection of cases from the Author's paper already referred to. It gives the average number of vehicles drawn, and the gross weight of the engine, tender, and train; the average distance run between the stopping stations; the average speed, including stoppages; the gross consumption of coal per train mile, and per ton gross per mile; also, in the last column, the equivalent speeds without stoppages, or such as would have been averaged had there been no stoppages, estimated in terms of an allowance or deduction in time of four minutes for each stoppage, actually made by the passenger trains, except for the Birkenhead trains, with which, owing to the frequency of the stoppages, the actual delay is only three minutes per stoppage.

In conclusion, it should be noted that the steam should always be kept up while the engine is running. In most of the systems in use, a considerable quantity of cold air is drawn into the flue-tubes, the strength of the draught towards the flue-tubes not allowing it to approach sufficiently near the surface of the fire

PERFORMANCES OF COAL-BURNING LOCOMOTIVE ENGINES, 1860.

WITH PASSENGER TRAINS.									
SYSTEM.	DESIGNERS.	RAILWAY.	Number of Vehicles.	Gross Weight of Engine, Tender, and Train.	Average Distance run between Stopping Stations.	Average Speed, including Stoppages.	Gross Consumption of Coal.		Calculated Equivalent Speed without Stopping.
							Per Train Mile.	Per Ton Gross.	
Long Fire-box and Combustion chamber. Mid-foathers, Combustion chambers. Long Fire-box and inclined Grate	Mr. McConnell	London and North-Western	13·2	Tons. 115·	Miles. 5·	Miles per Hour. 27·1	lbs. of Coal. 35·6 Hawksbury	lb. 31	Miles per Hour 42·
	Mr. Beattie...	London and South-Western	11·	102·	15·7	20·6	24·0 Griff.....	235	34·
	Mr. Cudworth	South-Eastern	13·2	116·	11·	26·8	26·0 Coking Coal	225	32·
	ORDINARY FIRE-BOXES.								
Door deflector	Mr. Douglas...	Birkenhead	8·	say 90·	2·8	19·1	28·45 Welsh ...	32	29·
Brick arch and Air-bars	Mr. Yarrow ...	Scottish North-Eastern ...	8·	say 86·	5·9	25·7	27·2 Scotch ...	32	36·2
Brick arch and Door deflector...	Mr. Connor...	Caledonian	7·5	say 88·	4·5	22·2	22·6 Scotch ...	26	33·3
Door deflector and Steam in Fire-box.	Mr. Frodsham	Eastern Counties	8·7	93·	5·3	21·	23·3 Staveley	25	29·
Plain Fire-box and Steam induction.	Mr. Clark.....	Great North of Scotland ...	10·2	109·6	3·3	19·	21·0 Scotch ...	19	32·
WITH GOODS TRAINS.									
ORDINARY FIRE-BOXES.	Mr. Douglas...	Birkenhead	32·	say 445·	...	...	60·3 Welsh	135	...
	Mr. Connor ...	Caledonian	28·	255·	6·8	11·9	37·3 Scotch	117	...
	Mr. Frodsham	Eastern Counties	26·6	228·	10·2	14·5	41·5 Staveley ...	182	...
	Mr. Clark	Great North of Scotland ...	14·3 18·8 27·	148· 186· 305·	4· 3·4 4·	16·4 17·3 14·3	24·0 Scotch	16 148 13	...
AVERAGE OF PASSENGER AND GOODS TRAINS.									
	Mr. Douglas...	Birkenhead	...	...	...	...	...	...	...
	Mr. Connor ...	Caledonian	17·	162·	5·3	16·	29·5	182	...
	Mr. Frodsham	Eastern Counties	17·4	161·	6·	18·8	32·4	2	...
	Mr. Clark	Great North of Scotland ...	18·8	186·	3·4	17·3	27·6	148	...

to mix with the smoke. In Mr. Connor's system, although the inclined plate or deflector at the doorway gives the air a downward direction, yet when it is under the action of a strong blast, the current undulates over the arch. In Mr. Douglas's and Mr. Frodsham's systems, the diverting action of the draught is still more injurious, because there is no assistance from a brick arch in bringing together the smoke and the air; the air does not strike upon the fire, but goes at once towards the tubes. On that account, the brick arch is a very useful adjunct in connection with the inclined entrance of the air into the box. In the plan of Mr. Ramsbottom, the air is introduced in too large a body through only two places, and therefore a portion of it must pass through unmixed. The air, where it enters the box, should be introduced at the proper level for immediate mixture with the smoke.

But if it is necessary to keep up the steam when the engine is working, it is also important to keep down the steam whilst the engine is standing at the stations, or running without steam on. The chimney-blower is required, in order to create a sufficient current of air in the fire-box to consume the smoke. Where tubes are placed in the front and back of the box, and induction-jets are used instead of a jet in the chimney, as the nozzles operate above the level of the fuel, the tendency is to prevent the draught through the grate, and thus to suspend the generation of smoke, as well as the consumption of fuel. For this reason, the steam is not so liable, in this system, to rise to a dangerous pressure.

Another important point is the question of management. It is desirable that any system employed should be capable of being easily managed; and as the difficulty principally occurs at high speeds with express trains, that which requires the least fuel and the least labour from the stoker is the best. With deflectors there is a large quantity of cold air introduced into the fire-box. In Mr. Connor's plan, for example, the sectional area of the entrance is $67\frac{1}{2}$ square inches, or 5 square inches per square foot of grate. In Mr. Ramsbottom's system it is 7 square inches per square foot of grate. In Mr. Frodsham's system, upon the Eastern Counties Railway, the area of entrance is $5\frac{1}{2}$ inches per foot of grate. In the Author's apparatus the maximum area is 4 inches per foot of grate.

In 1860 a plan was tried, with some success, on the Caledonian Railway, for supplying the air direct upon the top of the fire, through a short wide spout from the doorway. About the same time, the Midland Railway Company introduced a brick arch into the fire-box, in connection with a long deflector plate from the doorway, and sliding-doors on the outside of the fire-box, consisting of two half door-plates connected to slide simultaneously, together or apart, and thus to regulate

the supply of air by the doorway. Mr. Markham, of Derby, in a valuable paper on the subject,* stated that he obtained the most satisfactory results with a deflector-plate 3 feet in length, and a doorway 18 inches by 11 inches, giving 1.1 square foot of area for a grate of 14 square feet area; or 11.3 square inches of air-entrance for each square foot of grate. This is largely in excess (about three times as much) of what the Author has found necessary on his system, and it signifies that a very large surplus of cold air passes into the fire-box besides what is actually consumed, which appears to explain why Derbyshire hard coals evaporated only 6.7 lb. of water per lb. of coal, with his apparatus, whilst Durham coke evaporated 7.9 lb. per lb. of coke, or 18 per cent. more water; whereas, on the Author's system, it has been found that coal, with 4 square inches of air entrance per foot of grate, generally evaporated more water than was evaporated with coke.

FEEDWATER HEATERS.—In the application of feedwater heaters to locomotive engines, Mr. Beattie has laboured with considerable success, using the exhaust steam for the purpose. The results of the Author's trials of Mr. Beattie's heater in 1856 showed that a saving was found of at least 15 per cent. of fuel by use of the heater, as compared with cold water,—a conclusion which has been confirmed by the experience of others in locomotive practice. In Mr. Beattie's earlier form of heater, the feedwater was discharged, through perforations in the end of a pipe, into a chamber placed in front of the chimney, where the exhaust steam was freely admitted. By this plan the water was raised to a temperature varying from 180° to 190° with an ordinary blast, or 212° with a heavy blast. Mr. Beattie has more recently employed a surface heater, consisting of a steam-pipe from the exhaust within a water-chamber, the feedwater circulating in the annular space, in combination with a cistern below the foot-plate, into which the feedwater is delivered from the tender, through a ball-cock, to regulate the supply, and is dropped through a perforated plate. Into this chamber the exhaust steam also is discharged, after having passed through the annular heating-chamber. In this apparatus, though it is complicated and expensive, the water is well heated, but occasionally the influx of the water to the cistern has been prevented by the counter-pressure of the exhaust steam.

Mr. P. Stirling, of the Glasgow and South-Western Railway, tried Mr. Beattie's feedwater heater, and he found by comparison with the use of cold water that a saving of $11\frac{1}{2}$ per cent. of fuel resulted from the use of this apparatus.

The Author, in 1859-60, introduced a simple and compact feedwater heater, in which the

* See "Proceedings of the Institution of Mechanical Engineers, 1860."

steam from the blast-pipe is projected into a short tube, in conjunction with the feedwater, which is delivered in a thin annular sheet around the steam-nozzle. The steam forcibly impinges upon and breaks up the water into spray, and is instantly absorbed by the water, which may be heated to any degree of temperature.

FIG. 12.



FEEDWATER
HEATER, by
Mr. D. K.
Clark, 1859,
by exhaust
steam.

The steam operates partly by suction, in inducing the influx of the water, and partly by driving it before it, and so aiding the hot-water pump by the acquired momentum of the water. This apparatus has been employed on a non-condensing stationary engine, of twenty nominal horse-power, working at a pressure of steam of 60 lb. per square inch. In its first form, the temperature of the feedwater was raised 120° , and the saving of fuel by its use was 10 per cent. In the second form, the water was heated from 39° to upwards of 191° , the engine making forty revolutions per minute. A model of this apparatus was exhibited (fig. 12).

CHAPTER III.

ENGLISH LOCOMOTIVES.

The accompanying large Table contains the principal particulars of the locomotive engines exhibited, both English and foreign. The first and the most conspicuous locomotive engine in the English Department is the No. 373 passenger engine, exhibited by the London and North-Western Railway Company, designed with special regard to the running of the express trains on the Southern Division. Only three engines were made of this class, as it was found to be heavy on the road, and heavy on the fuel. It is an engine of maximum dimensions, and, indeed, beyond the capacity of the narrow gauge for proper working. With cylinders of 18 inches diameter, and a stroke of 24 inches, 7 feet 6 inch driving-wheels, and 25 square feet of grate, it weighs $34\frac{3}{4}$ tons in working order, of which there are fully $14\frac{1}{4}$ tons of driving-weight at one pair of wheels. With the tender, weighing 25 tons with fuel and water, the total mass to be moved amounts to about 60 tons, exclusive of train-weight. The boiler has been designed, like the other already described (fig. 1), for burning coal. The combustion-chamber having been found insufficient for the purpose of mingling the combustible gases and consuming them before entering the fire-tubes—which, indeed, was scarcely to be expected, being only 2 feet 8 inches in length—the fire-box has been fitted with fire-brick arches inside, and with deflecting plates in the doorways. The grate is 7 feet

long, in two parallel strips, and the enormous amount of heating surface, $242\frac{1}{2}$ square feet, has thus been attained in the fire-box and the combustion-chamber, making what is called “direct” heating surface, more than has before been attained on the narrow gauge. But the advantage of “direct” surface, or that which is exposed to the radiant heat of the fire, depends entirely upon its being within a reasonable distance of the grate; whereas, in this fire-box, the crown is 6 feet 3 inches above the grate; and the upper portions of the surface are nearly inoperative for evaporation. The first concern is to bring the surface near to the fire, or the fire near to the surface; hence the efficient performance of Mr. Cudworth’s boiler (fig. 3) with the elevated inclined grate, in which not only the lateral but the horizontal surface is thoroughly heated by direct action; and were it not for the greater labour and attention demanded by this triangular form of fire-box, it would probably supersede the cubical forms, of which Mr. McConnell’s and Mr. Beattie’s are types.

The great extension of fire-box and combustion-chamber has led to the curtailment of the flue-tubes to 9 feet 4 inches in length, and to the attempt to compensate for this by packing 214 of them together at $\frac{1}{2}$ -inch distances apart, making 980 square feet of heating surface. There is a general belief that heating surface is mechanically the equivalent of evaporating power. This is a mistake. Besides surface, circulation is wanted,—the circulation of the water to, and the steam from amongst, the tubes. The evaporative power of a less number of tubes, placed at $\frac{3}{4}$ inch apart, would have been decidedly greater than that of the tubes as they are. The driving and leading springs are connected by a compensating beam, which must give an unsafe freedom of action to the engine at high speed.

The other engine, the “Lady of the Lake,” also exhibited by the London and North-Western Railway Company, is one of a numerous class designed with special regard to the running of express trains on the Northern Division of the line. This engine contrasts in several respects with No. 373. It weighs only 27 tons in working order, and the tender $17\frac{1}{2}$ tons, making a total of $44\frac{1}{2}$ tons, as against 60 tons for No. 373. The fire-box is of the ordinary form, with little more than half the grate-surface of No. 373, and is fitted for coal burning, with a brick arch and air-openings in front, as already described and shown in fig. 8. The heating surface of the fire-box is little more than one-third that of No. 373; and there are fewer tubes, but then they are $\frac{1}{2}$ inch apart. No. 373 gains the advantage of the “Lady” in the greater size of blast-orifice, which is $5\frac{1}{4}$ inches diameter for the former, and $4\frac{1}{4}$ inches for the latter, owing to the larger grate of No. 373, which does not require the same sharpness of blast to draw the air through. The proportions in

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question are here brought together for comparison :—

No. 373. LADY OF THE LAKE.			
Area of Fire-grate.....	25 sq. ft.....	15 sq. ft.	
Heating surface of Fire-box.....	242·5 do. ...	85 do.	
Do. Tubes...	980·5 do. ...	1,013 do.	
Do. Total ...	1,223·0 do. ...	1,098 do.	
Driving-weight.....	14½ tons...	11½ tons.	

The annexed table contains the results of the performance of engines of the same classes respectively, in which the weights of the trains are averaged from actual observations, being 8½

tons per vehicle, with passengers and luggage ; the vehicles averaging 6 tons 11 cwt. nett, and 39 cwt. per vehicle being allowed for the carried weight. It appears that whilst the Southern engines have only 36 per cent. more train-load, they consume 55 per cent. more coal than the Northern engines. The consumption per ton, gross weight, including the engine and tender, is at the rate of 0·26 lb. per ton per mile for the Southern, and 0·23 lb. per ton per mile for the Northern, which shows pretty clearly that there is no mechanical superiority in the Southern boiler, with its extensive direct heating surface, over the Northern boiler, of the ordinary type.

RESULTS OF PERFORMANCE OF " No. 373," AND THE " LADY OF THE LAKE," EXPRESS ENGINES ON THE LONDON AND NORTH-WESTERN RAILWAY.

ENGINE.	Months at Work.	Miles run to 31st October, 1862.	Average Weight of Train (at 8½ Tons per Vehicle).	Gross Weight of Engine, Tender, and Train.	CONSUMPTION OF COAL.		
					Per Mile.	Per Ton of Train per Mile.	Per Ton Gross of Engine, Tender, and Train per Mile.
SOUTHERN DIVISION.					lb.	lb.	lb.
No. 972.....	6	10,560	95·07	...	42·13	0·44	...
No. 975.....	9	23,906	101·55	...	41·48	0·41	...
Mean of Engines of the class of "No. 373"			99·56 (Averaging 11·7 Vehicles.)	159·36	41·68	0·42	0·26
NORTHERN DIVISION.							
No. 44, "Harlequin"	32	102,714	72·25	...	26·85	0·37	...
No. 196, "Leander"	22	76,980	72·35	...	25·76	0·36	...
No. 229, "Watt"	34	105,717	74·00	...	27·43	0·37	...
Mean of Engines of the class of the "Lady of the Lake."			72·93 (Averaging 8·58 Vehicles.)	117·35	26·77	0·37	0·23

Regarding, again, the engines as carriages, the great height of the centre of the boiler of No. 373, 7 feet 5½ inches above the level of the rails, is excessive, and tells upon the rails when the engine sways. In the " Lady of the Lake," though she has driving-wheels as large as those of No. 373, the centre is 11 inches lower; and this, in connection with a compact wheel-base and a balanced driving-wheel, produces a safe, steady, and easy-running engine.

In the details of No. 373, there are some noticeable novelties. It has Krupp's steel axles and steel tires. The pistons are of solid wrought iron, with two small brass packing-rings, kept tight by the pressure of steam admitted behind them. They are commendable for their lightness, being about half the weight of ordinary

pistons. Feed-pumps are displaced by Giffard's injector, which will be noticed in another place.

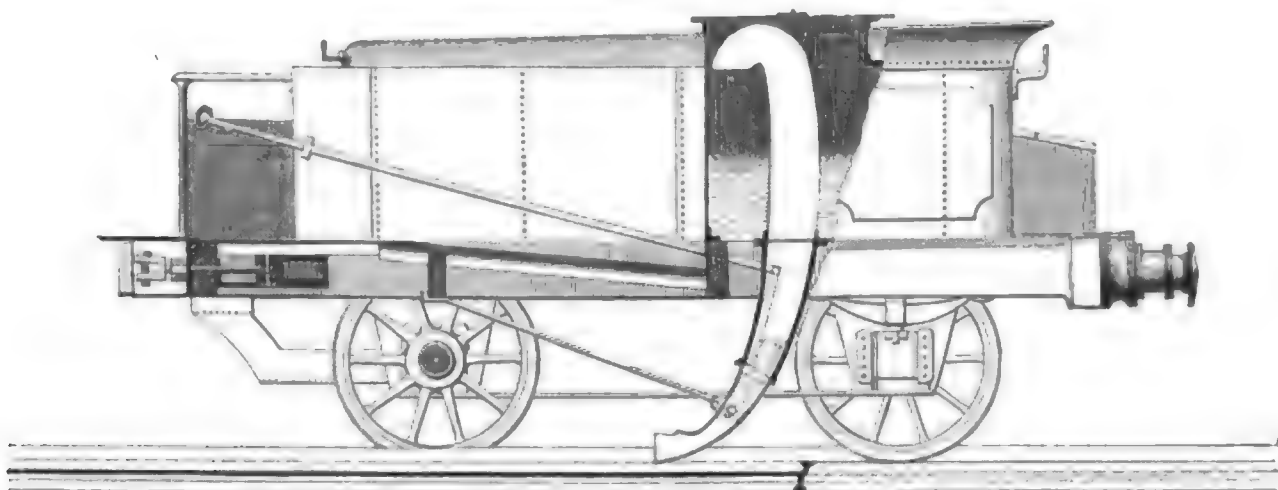
The " Lady of the Lake," also, is fed by two of Giffard's injectors. It is fitted with Mr. Ramsbottom's duplex direct-action safety-valve, in which a pair of valves are pressed down by a cross-bar and a helical spring attached to the middle of the bar, between the valves, — a decidedly superior system to the weighted lever. It cannot be tampered with, and is much more prompt in discharging an excess of steam, as it opens wider for a given excess of pressure. It is similar in principle to Mr. J. V. Gooch's single direct-action valve. The smoke-box is fitted with a descending hopper, through which ashes and ignited cinders are allowed to escape from the smoke-box; thus overheating is prevented. The

cylinders and valve-faces are lubricated by means of gravity-lubricators, in which the water held in suspension in the steam is deposited in the vessel containing the oil, displacing it, and forcing it over into the cylinder, whence it is swept off by the steam over the working surfaces. The pistons are of cast iron, in one piece, fitted with Mr. Ramsbottom's packing-rings, made of square wrought-iron wire, hard drawn, and bent to such a form as to give uniform pressure round the piston. The reversing gear is worked by a screw and hand-wheel, instead of the usual long lever and notched sector, than which it is much more easily worked, saving the engineman a great deal of fatigue. It is applied to nearly two hundred engines. The driving-wheels are very fine pieces of forging.

The tender of the engine, exhibited with it, has six wheels, and weighs, empty, $9\frac{1}{2}$ tons; full,

$17\frac{1}{2}$ tons, the load equally distributed on the wheels. It is fitted with Mr. Ramsbottom's apparatus for picking up water whilst running, illustrated by figure 13; in which a scoop is let down from the bottom of the tender, and dips into the water contained in a long open trough between the rails, from which it is scooped up into the tank while running. A minimum speed of 22 miles per hour is required for this operation. Three such apparatus have been laid down, and are at work, on the London and North-Western Railway; and their advantages are, that the size and weight of the tender, for running a given distance, may be reduced, the number of stoppages lessened, and time saved. An express engine has thus been enabled to run the whole distance from Holyhead to London, 264 miles, in one continuous run, at an average speed of 42 miles per hour.

FIG. 13.



MR. RAMSBOTTOM'S SELF-FEEDING TENDER, for picking up Water whilst running.

The next is an express passenger-engine, the "Don Luiz," for the South-Eastern Railway of Portugal, by Messrs. Beyer, Peacock, & Co., of Manchester, whose designs are characterized by elegance, thoroughness, and finish in form, arrangement, and detail. This engine is a type of the prevalent style of English inside-cylinder express engines. The framing is composed of two pairs of longitudinal bars or slabs, running straight from end to end, cross-braced by the cylinders, the foot-plate, and various cross-plates. The broad and comprehensive slab frame-plate here noticeable was introduced by Mr. Beyer many years ago, and is now generally adopted in English practice. The extension of the two inside longitudinal slabs alongside the fire-box, formerly stopping short in front of it, is an important concession to good principle, and is a first-rate practice, as it connects the steam-cylinders, driving-axle, drawplates, and bolts directly and immovably together, and bears and transmits the entire strain of the steam in the cylinders, and the tractive force, to the train. The boiler is thus relieved of all strain from the working parts, from which formerly it was not

free, and suffered accordingly. The driving-axle is made with only two bearings, inside the wheels, for which the guards are forged on the inside frame-plate, and the fore and hind axles have their bearings outside the wheels,—an arrangement originated by the late John Gray, and now generally adopted for its simplicity, and for the greater firmness of the frame and the increased duration or "life" of the crank-axle. The steam-strain is, in fact, confined to the two inside frame-plates and to the inside bearings of the axle, close to the cranks. The fore and hind wheels are 3 feet 9 inches diameter, the drivers being 7 feet; the fore wheels have been thought rather too small, and no doubt there is space in the engine for enlarging them, but they would have departed from uniformity with the six tender-wheels, which also are 3 feet 9 inches. The least that can be said is, they run fast enough.

The short cast-iron blast-pipe, reaching just above the level of the upper row of the flue-tubes, is to be remarked. This level of blast-orifice gives the best results, creating a better draft with a wider orifice, as compared with

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higher blast-pipes, and was arrived at by Mr. Peacock by means of a series of well-arranged experiments on the Manchester, Sheffield, and Lincolnshire Railway. The low blast-pipe is now generally employed. The first blast-pipes were carried some distance into the chimney, and had very contracted orifices and a sharp blast, with much back pressure on the piston.*

The "straight-link" motion of Mr. Allan is applied to work the slide-valves of this engine. It is a pleasing variety of the expansion-link, and will be described in another place.

The boiler, facilitated by the width of gauge, 5 feet 6 inches, has a large square fire-box, 4 feet 10 inches each way over the outside shell, and has a large diameter of barrel, 4 feet 2 inches, which gives abundance of steam and water space. Nevertheless, for effectiveness of heating surface, a fire-box of oblong form would have been better. There are 219 2-inch flue-tubes, placed at 9-16ths of an inch apart. Had the tubes been only $1\frac{1}{8}$ inch diameter, which, upon the whole, is the best size, and placed in the same position, the extra clearance so obtained for circulation would have improved the evaporative efficiency. The fire-box is adapted for coal burning, with a brick arch, a deflector-plate from the doorway, and a sliding door, on the plan, already described, in use on the Midland Railway.

The express passenger engine and tender (Plate I.), exhibited by Messrs. Neilson & Co., Glasgow, were built by them to the designs of Mr. Benjamin Connor for the Caledonian Railway, of which Mr. Connor is the locomotive superintendent. The class of engines of which this is one were designed with a view to economy rather than speed, and are employed on main-line service between Glasgow and Carlisle, taking their turn of all the trains, fast and ordinary. The experience that had previously been acquired of the durability and general economy of the 7-foot driving-wheel over the original 6-foot wheel passenger engines of the line, suggested to the designers that a further extension of the principle of enlargement of driving-wheel would be advantageous and satisfactory. It is a fine, well-constructed engine, standing gracefully on its wheels; large yet compact, and qualified to run at any speed with ease and steadiness. Its striking appearance, with its magnificent wheel—the largest in the Annex—secured for it the choice of his late Highness the Pacha of Egypt, who wanted an express engine to carry him at 70 miles per hour. This engine has grown out of the old Crewe pattern of engine, originally introduced on the Caledonian line by the late Mr. Locke, the chief engineer, and successively modified by Mr. Robert Sinclair (whose peculiar chimney-top—the bellow's-mouth—is retained), and by Mr. Connor, to meet the grow-

ing requirements of the traffic. This engine weighs, in working order, 30 tons 13 cwt., of which the driving-weight amounts to $14\frac{1}{2}$ tons. This driving-weight is in excess of any other in the building, if that of the North-Western inside-cylinder engine be excepted: the largeness of the driving-wheel, 8 feet 2 inches, may prevent in some degree the injurious effects of concentrated loads on the permanent way. The counterweights are compactly forged into the rims of the wheels, extending over a third of the circumference, and though a little more weight is thus requisite to complete the balance, it sweeps gently over the rails when the engine is in motion, without the sledge-hammer effect of a revolving cubical mass, compressed into the space between two or three spokes. For such a large wheel, also, the constructors have, with commendable caution, thickly planted the spokes, at 10-inch centres, on the rim: the stiffness of a spoke decreases in a rapid proportion with its length—inversely as the cube of the length,—so that a spoke for an 8-foot wheel will be only half as stiff as a spoke of the same scantling for a 7-foot wheel. The driving-axle is of cast steel, manufactured at the works of the Caledonian Railway; the tires are of Krupp's steel.

The framing of the old Crewe engine is retained in this one, giving outside bearings to the fore and hind axles, and insides to the driver. In this respect the "Lady of the Lake," a recent Crewe engine, is at variance with the older practice, having but one longitudinal frame-plate on each side, with inside bearings for all the wheels; and, with outside cylinders, it may very properly become a question whether the cylinders should be, as they are in the Caledonian engine, so rigidly united to the outside frame-plates, which carry two pairs of wheels and axles, and which, of course, transmit the shocks of the road to the cylinders. The foot-plate is judiciously provided with a housing for the engineman and stoker—a most important provision for their comfort, and for the safety of railway trains. Plain fence-plates are now commonly applied to engines across the back of the fire-box, and they are useful. But the housing is better, and it is marvellous that the application of so needful a protection should have been so long neglected.

The slide-valves are made with $1\frac{1}{2}$ -inch lap at each end, in pursuance of the conclusion arrived at by Mr. Sinclair as to the peculiar importance of long-lap and long-travel for the valves of outside cylinders, unquestionably facilitating the free exhaust of the steam, at high speed, from exposed cylinders, in which the steam is found to be more or less condensed: moist steam is not so active as dry steam, and if not freely discharged it exerts an excessive back pressure on the piston.

The boiler is fitted with the brick arch and door deflector, already described, applied by Mr. Connor to all or most of his engines for burning coal; 192 flue tubes, $1\frac{1}{8}$ inch diameter, and

* For a detailed account of Mr. Peacock's experiments, see "Railway Machinery," page 134.

placed at $\frac{1}{8}$ -inch clearances, in a 3 feet 10 inch barrel. Giffard's injectors are employed.

The average work of engines of this class on the Caledonian Railway is a load of nine heavy carriages, being composites of four compartments, and third class with five compartments; the running speed with local trains is about 35 miles per hour, and with fast trains 40 miles per hour. The average consumption of coal in February, 1863, with prevalent high winds, is stated to have been 25 lb. per train-mile; in the summer of 1862 it averaged $21\frac{1}{2}$ lb. per mile; they frequently take, without assistance, 14 loaded carriages up the Beattock incline, 10 miles long, at the rate of 30 miles per hour. The gradient is 1 in 84 for four miles, and 1 in 75 for six miles.

The "Manchester," exhibited by Messrs. Sharp, Stewart, & Co. (Plates II. and III.), and built for the London, Chatham, and Dover Railway Company, is a first-rate six-coupled-wheel goods engine, with 5-foot wheels and 17-inch cylinders, of maximum power, adapted for the heavy loads, heavy gradients, and the ultimately high speeds of that line. It is a fine engine, of excellent workmanship and magnificent proportions. It weighs, empty, $28\frac{1}{2}$ tons; full, 32 tons; yet the distribution of this ponderous load is, by a happy distribution of material, nearly equalised over the three axles, to the advantage of the permanent way, viz:—

	TONS CWT.	
Leading wheels	10	13
Middle do.	11	11
Trailing do.	9	17
TOTAL	32	1

The fire-box is 8 feet long externally, with an inclined grate on Mr. Cudworth's system, for burning coal, which has already been described at length. The hind axle is thus admitted under the fire-box about one-third of its length, and is enabled to take its fitting share of the load, whilst the length of wheel-base is moderated, and is bisected by the middle axle,—advantages peculiar to Mr. Cudworth's system. The fire-box measures 7 feet $3\frac{1}{4}$ inches long inside, divided longitudinally by a "midfeather," and has $27\frac{1}{2}$ square feet of grate. There are 189 flue-tubes, 2 inches diameter, and $\frac{1}{8}$ inch clear, within a 4 feet 2 inch barrel. These are good proportions, according to current practice; but had there been only 160 tubes at $\frac{3}{4}$ inch clearance, in such a large barrel, it would have been decidedly better. The boiler is fitted with Giffard's injector. The housing for the enginemmen, with windows in the front and sides, is very good and complete.

The frame is composed of four longitudinal plates, carried from end to end, with suitable cross-plates to bind it. The outer plates are each of one thick slab, of considerable depth between the guards, with intervals slotted out, combining great strength and lightness. In this engine, the usual construction of outer frame with double plates and timber packing

has thus been superseded. The driving axle has four bearings, two inside and two outside, and the extreme axles have only outside bearings; and the old antagonistic action is set up, arising out of the unequal wear of the inside and outside bearings,—the inside bearings next the crank, receiving the full strain of the steam, wearing faster than the outsides, leaving the cranks unsupported, and shortening the duration of the axle; overstraining in that way also, and loosening the connections of the inner and outer frame-plates. On the contrary, this arrangement admits of large outside bearings and capacious axle-boxes for all the axles, an advantage which unfortunately the narrow gauge does not permit for inside crank-axle bearings. It is at best a compromise, and the national gauge should have been six inches wider. The drawing tackle of this engine is connected exclusively to the frame.

The valve-gear is very substantially and firmly arranged. The expansion-link is shifted, and the slide-block is not overhung, but hung between the ends of the link which carries it.

The "Manchester" is said to be capable, with a working pressure of 120 lb. per inch, of taking a load of 480 tons on a level at 20 miles per hour, or a load of 250 tons up a gradient of 1 in 100 at 15 miles per hour. The engine was purchased by his late Highness the Pasha of Egypt for the Egyptian Railway.

The next engine is a six-coupled goods engine, of excellent workmanship, exhibited by Messrs. Wm. Fairbairn & Sons, Manchester. It was made for the Midland Railway to the design of Mr. Kirtley, the locomotive superintendent, which appears to have been based on the "Jenny Lind" model, brought out at the "Railway Foundry," Leeds, and now a matter of history. It has the ordinary rectangular fire-box, and is fitted on the Midland system, already described, for burning coal, with $14\frac{1}{2}$ square feet of grate; the cylinders are 16 inches diameter, with 24 inches stroke. The engine weighs in working order 32 tons 5 cwt. It is a thoroughly good engine of its kind, and is a type of the powerful goods engines usually met with on the old main lines of railway. It may be usefully compared with the "Manchester," just described, which is an engine of the same weight and calibre, of a different and more recent class. In the first place, the weight is not so well distributed on the wheels, being considerably in excess on the leaders, thus:—

	MIDLAND. TONS CWT.		"MANCHESTER." TONS CWT.	
Leading wheels	12	6	10	13
Middle do.	11	5	11	11
Trailing do.	8	14	9	17
TOTAL WEIGHT	32	5	32	1

Showing, in the Midland engine, 3 tons 12 cwt. more on the leading than the trailing wheels, and in the "Manchester" only 16 cwt. more

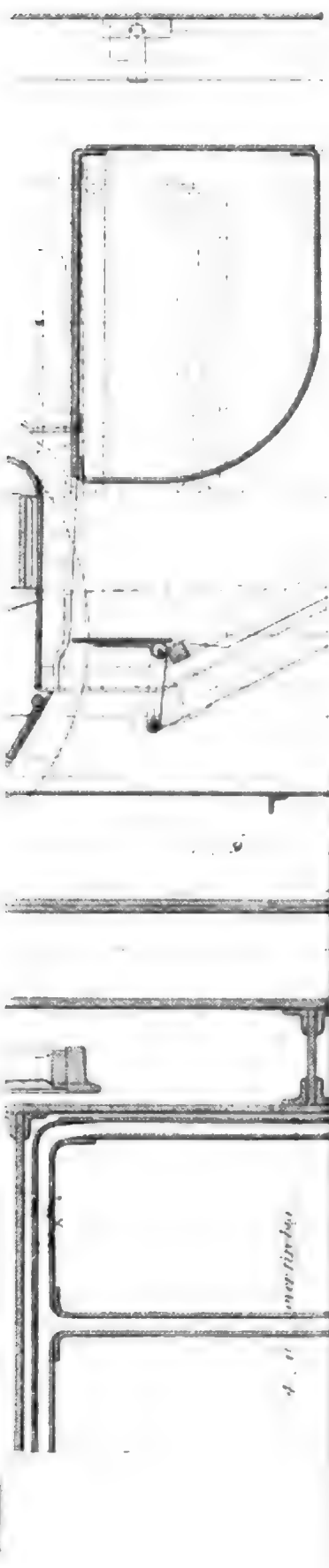
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weight; the wheel base of the Midland engine being 16 feet 6 inches, or 1 foot more than that of the other, as the vertical fire-box keeps back the hind axle. The frame of the Midland engine, like the other, has four longitudinal plates, with four bearings to the driving-axle, and outside bearings to the other axles; but the inside frame-plates stop short at the fire-box, and are fastened to it by sliding joints, allowing for expansion of the boiler. The draw-plates are riveted to and across the back of the fire-box, from which the whole of the drag is taken; and of course, as the tractive force must be transmitted from the outside frame-plates to the fire-box, they are very strongly united by brackets to the fire-box, for that purpose. Thus the whole area of the frame behind the fire-box remains unemployed, except as standing ground. This is an objectionable feature in the Midland engine, without any countervailing advantage. The steam-power is not only transmitted circuitously, tending to overstrain and buckle the framing, but it arbitrarily subjects the boiler, already highly strained, to an unnecessary additional fatigue, which is now beneficially avoided in more recent practice. The flue-tubes are well designed, being 2 inches diameter, 180 in number, and placed at $\frac{5}{8}$ inch clearance, in vertical rows, which accounts for the high character of the Midland engines for keeping up the steam. The boiler is put together without angle-iron, the plates being flanged at the end; the steam-dome also is flanged and formed in one piece. For this purpose, Alton & Fernie's patent thick-edged plates are used: they are rolled to $\frac{5}{8}$ inch and $\frac{3}{4}$ inch thick to allow material to work upon. The advantages claimed for the thick-edged plates in their application, are that they save a joint, including a row of rivets, and are stronger than angle-iron joints; the joints are cheaper and easier to make, and are not subject to grooving; the dome-joints being faced in the lathe, bad joints are prevented.

Of the mixed engines, Sir W. G. Armstrong & Co., Newcastle-on-Tyne, exhibited a six-wheel, four-coupled engine, made for the East Indian Railway, with cylinders outside, and the hind-wheels coupled. The wide Indian gauge of rails, 5 feet 6 inches, admits of a large fire-box, 4 feet $1\frac{1}{2}$ inches square inside, with a grate of 17 square feet, which is too large for the cylinders and the wheels. The flue-tubes, 157 in number, are 10 feet 11 inches long, $2\frac{1}{4}$ inches outside diameter, and they clear each other by half an inch. These proportions would be much improved by reducing the tubes to 2 inches diameter, at $\frac{3}{4}$ inch clear: the reduction of heating surface would be more than amply compensated by the increased facility for circulation.

The total weight of the engine in working order is $32\frac{1}{2}$ tons; and $21\frac{1}{2}$ tons is available for adhesion, but very unequally divided. The leading wheels are 3 feet 7 inches diameter, and the six wheels of the tender are 3 feet 9 inches, making only 2 inches difference. Probably the

2 inches were taken off the leading wheels to get them more forward, and leave more weight for adhesion, and no doubt they are at present overloaded. But it would have been better in that case to have reduced the tender wheels to the same size, for convenience of exchange and repairs.

The slide-valves have only $\frac{3}{4}$ inch lap, which is inadequate for a 16-inch outside cylinder, in which there is always more or less condensation of steam. The back pressure on the piston at high speeds must be something considerable, as an insufficient lap prevents a full and free opening to the exhaust, which is required to be greater for moist than for dry steam.

The foot-plate is furnished with a screen-frame to completely protect the enginemen from the sun, and to ensure ample ventilation,—an object of vital importance in India. It is a very complete and carefully considered screen; the use of a weather-board being unfavourable for ventilation.

Mr. Robert Sinclair, locomotive superintendent of the Great Eastern Railway, exhibited a mixed engine of his design, with six wheels, four coupled, and outside cylinders, constructed by Messrs. Robert Stephenson & Co. The framing has but one longitudinal plate on each side from end to end, with inside bearings for all the wheels. With 17-inch cylinders and 6 feet 1 inch driving-wheels, which are more powerful than in Sir Wm. Armstrong's engine, the boiler is lighter, having only $13\frac{1}{2}$ square feet of grate as against 17 feet, with a shallower fire-box and a smaller barrel; hence the total weight of the engine is less, and the weight is more equally distributed on the wheels, thus:—

	SINCLAIR. TONS CWT.			ARMSTRONG. TONS CWT.	
Leading wheels	11	2	.....	11	9
Middle do.	10	11	.....	12	11
Trailing do.	10	1	.....	8	14
TOTAL	31	17	.....	32	14

The leading wheels, 3 feet 7 inches, are also very properly made uniform with the six tender wheels. The engine is reported to have run 45,000 miles without repairs, for which satisfactory result it is indebted to the excellent design and workmanship; no doubt, also, to the favourable distribution of the weight, and to the material, of the tires—of Krupp's steel—which were apparently very little worn. A pair of tires which had run 68,000 miles showed a wear of about $\frac{1}{4}$ inch on the tread. Several of the driving and trailing wheel-tires of engines of the same class have run 60,000 to 70,000 miles without re-turning. The duration of the tires is estimated at 100,000 miles on the leading wheels, and 150,000 miles on the middle and trailing wheels; but none have yet been worn out.

In the barrel of the boiler, 3 feet 10 inches diameter, there are 192 flue-tubes, $1\frac{7}{8}$ inch diameter, with $\frac{3}{4}$ inch clearance, which are fair proportions. The fire-box is fitted for burning

coal on Mr. Frodsham's system, already described (fig. 11).

The slide-valves have $1\frac{1}{4}$ inch lap, with $5\frac{1}{2}$ inches travel in full gear,—very suitable proportions for outside cylinders. Mr. Sinclair, as already observed, appears to have been the first to apprehend the special importance of long-lap valves for quick running and free exhaust in outside-cylinder engines. In 1846 he specified $1\frac{1}{4}$ inch lap and 5 inches travel for the first engines on the Caledonian Railway.

Engines of this class are stated to work passenger trains averaging from 15 to 18 carriages, maximum load 35 carriages, at an average speed of 25 miles per hour, consuming 25 lb. of coal per mile. They are also stated to work goods trains consisting of 35 waggons, gross weight 300 tons, at an average speed of 20 miles per hour, consuming 36 lb. of coal per mile.

Of the tank locomotives exhibited, that of Messrs. G. England & Co., London, weighing $17\frac{1}{4}$ tons in working trim, is the largest. It was designed for branch lines. It has six wheels on a 10-foot base; four coupled wheels 4 feet diameter, and 11-inch cylinders. It is neatly arranged with two tanks, to hold 520 gallons, very conveniently placed on the foot-plate, one on each side, enclosed out of view by a fence carried nearly from end to end. Of the weight, which is equally divided on the axles, two-thirds is available for adhesion. There are 153 flue-tubes, $1\frac{1}{2}$ inch diameter, with $\frac{1}{2}$ inch clearance, the barrel being 3 feet 8 inches diameter; which are good proportions.

The next is a compact, neat, and serviceable little engine, by Messrs. Manning, Wardle, & Co., Leeds (Plate IV.), specially adapted and extensively used for collieries, iron-works, and public works. This engine was employed, under the Author's superintendence, in conveying the machinery from the unloading cranes, on trucks, to or near its destination, on lines of rails in the Western Annex,—a duty in which the engine was of essential service. It has 9-inch outside cylinders, and four wheels coupled, 2 feet 9 inches diameter, on a base of 4 feet 9 inches. The area of grate is 4.9 square feet. It has 55 flue-tubes, 2 inches diameter, and $\frac{1}{8}$ inch clear, amply sufficient for circulation. The weight, in trim, is $10\frac{1}{4}$ tons, equally distributed. The water-tank is placed upon the barrel of the boiler, and holds 252 gallons of water. The coke-boxes hold $7\frac{1}{2}$ cwt.; Giffard's injector is employed. With a working pressure of 120 lb. per inch in the boiler, the exhibitors assume an effect in mean pressure of 60 lb. in the cylinders, which is too low, but errs on the safe side, and for which they estimate the extreme tractive power equal to moving 206 tons; the maximum power of the engine is no doubt considerably greater.

The last and smallest engine exhibited in the English section is a tank-engine, for iron-works and collieries in South Wales, by the Neath Abbey Iron Company, on a gauge of 2 feet

8 inches, with 8-inch cylinders, and four coupled cast-iron wheels 2 feet 4 inches diameter, at 4-feet centres. The centre of the boiler is only 2 feet above the rails. The boiler has $3\frac{1}{4}$ square feet of grate; 59 flue-tubes, $1\frac{1}{4}$ inch diameter and 6 feet long; total heating surface, 181 square feet; gross weight, 6 tons 17 cwt. The tank is on the back of the boiler. The engine is carried on volute springs. The engines employed in the Neath Abbey Works have a run of 1,665 yards, or nearly one mile, with gradients varying chiefly from 1 in 15 to 1 in 26, with a small portion 1 in 100; the engines take up the return empty waggons to the coal-pits, the full ones going down. With 80 lb. steam, the regular duty of the engine is to take up 16 empty waggons or trams weighing in all 6 tons 9 cwt. (nearly the weight of the engine), in 7 minutes, or at the rate of 8 miles an hour. It can take up at the same speed 12 waggons, weighing 4 tons 10 cwt., with 66 lb. steam.

Mr. A. Allan, Perth, exhibits his "straight-link motion" for working the valves of locomotives. Its peculiar features are the expansion link and the mode of suspension. Ordinary expansion links are curved, forming a segment of a circle struck with a radius equal to the length of the eccentric rods, or of the radius links according to the arrangement. But Mr. Allan's link is straight, and the reversing, or the regulation of the expansion, is effected by a double action upon both the expansion link and the radius link, which being connected to a double-reversing lever, are moved in contrary directions; and thus, for the purpose of reversing, each is moved through only one-half the space vertically that either requires when moved alone, as in the ordinary gear. The application of the two opposite movements, further, permits the use of a straight link, with which the lead of the valve remains nearly constant for various degrees of expansion. The movements imparted to the valve are quite as good as with other links; the system is more compact and is perhaps more easy of manipulation (fig. 14).

Mr. Allan also exhibited an atmospheric pressure-gauge, the principle of which consists in indicating pressure either above or below that of the atmosphere, by the more or less compressed or expanded condition of a measured quantity of air contained within the gauge; this is acted upon by the pressure through water or other fluid contained within a bent pipe, which is attached at one end to the gauge, and at the other end to the boiler or vessel containing the pressure to be indicated; the surface-line of the water, as seen in a glass-tube attached to the body of the gauge, indicates the extent of pressure on a graduated scale. The column of air under compression is of a taper form, to equalize the scale for the higher and lower pressures. Means are provided for testing the gauge and renewing the supplies of air and water; and it is stated that the gauge works satisfactorily (fig. 15).

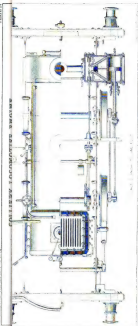
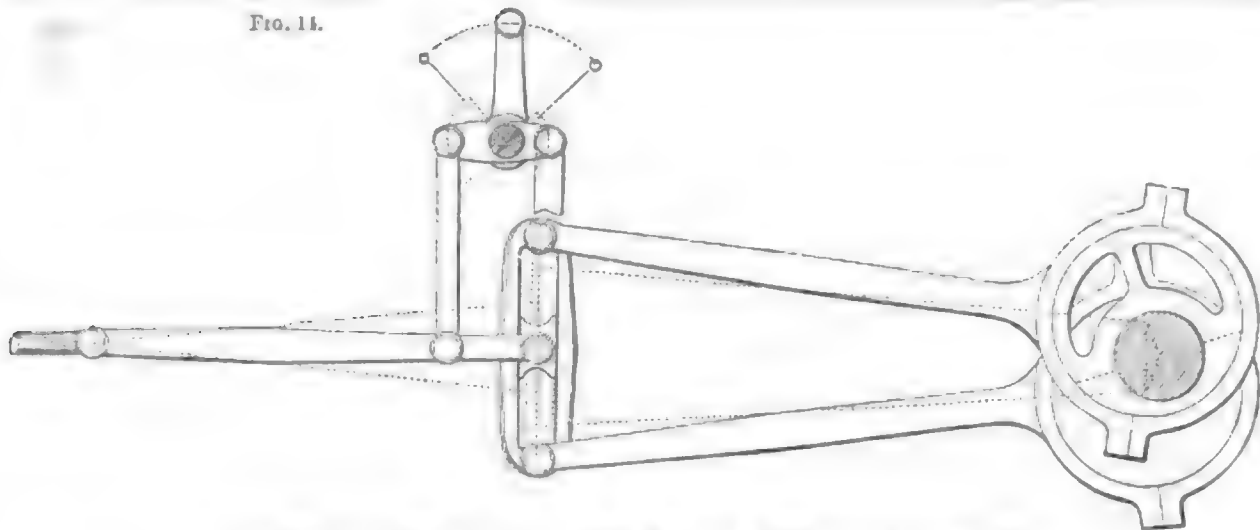
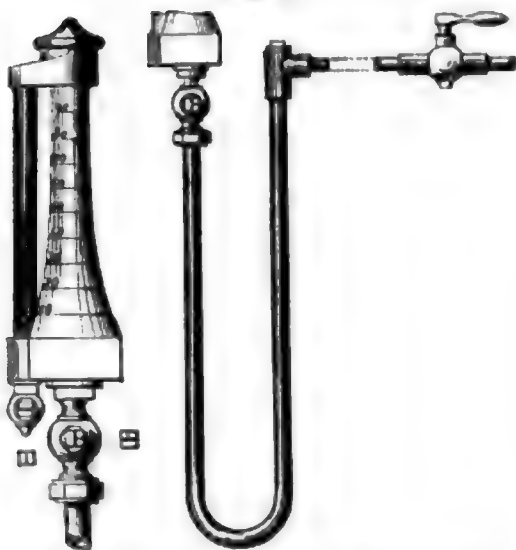


FIG. 14.



STRAIGHT-LINK MOTION, by Mr. A. Allan, Perth; for the Valve-gear of Locomotives.

FIG. 15.



ATMOSPHERIC PRESSURE-GAUGE, by Mr. A. Allan for Steam Boilers.

Mr. Nathaniel Grew, London, exhibited a model of a locomotive engine for running on ice, reported to have been successfully at work in Russia, during last winter, on the river Neva, conveying passengers and goods between St. Petersburg and Cronstadt. The engine is carried by a sledge under the fore part, and a pair of driving-wheels 5 feet diameter at the back of the fire-box, worked with an intermediate shaft, and a pair of outside cylinders, 10 inches diameter by 22 inches stroke. The circumferences of the wheels are studded with steel spikes, to obtain the necessary adhesion for traction. The engine is steered by turning the sledge, in front, by means of a screw and worm-wheel, and a pinion gearing into a circular rack fixed to the sledge. The proportion of the weight of the engine carried by the sledge is supported on four springs, with an allowance for lateral traverse. The engine weighs, in working trim, about 12 tons, of which, no doubt, more than half is carried by the sledge, and less than half by the wheels, on account of their extreme position, without any power of adjustment. The engine is reported to have attained a speed

of 18 miles per hour, with a gross load of 20 tons. There are, no doubt, considerable practical difficulties to overcome; for example, the necessity for providing adhesion artificially, and the resistance of snow to the advance of the sledge. Mr. Grew's engine is a very creditable application of the locomotive, in a novel direction (fig. 16, page 18).

CHAPTER IV.

FOREIGN LOCOMOTIVES.

FRANCE.—The French department contained examples and designs of various classes of engines, some of them not known in this country. The first is an ordinary passenger engine exhibited by the Orleans Railway Company, made by them to the designs of M. Forquenot, locomotive superintendent. It has outside cylinders, with the valves and valve-gear outside the cylinders and crank-pins. The fire-box is constructed for burning coal on the system of M. Tenbrinck, with a long sloping grate, and a water partition or midfeather across the fire-box, above and nearly parallel to the grate, so as to deflect the flame towards the door, and meet the air admitted there. These are merely varieties of English practice; the outside gearing is objectionable as, besides its being exposed to accident, the wear of parts affects injuriously the working of the valves in regulating the movements of the steam, in a much greater degree than when inside of the wheels; the fire-box combines some of the features of Mr. Cudworth's and Mr. Beattie's systems. Giffard's injector is applied, with M. Pradel's modification, in which the construction is simplified by omitting the mechanism for varying the supply of water. The axles are lubricated with oil from below by means of cotton stumps, which lift the oil by capillary attraction from a reservoir in the bottom of the axle-box.

The Orleans Railway Company exhibit also a drawing of a goods engine, with eight wheels

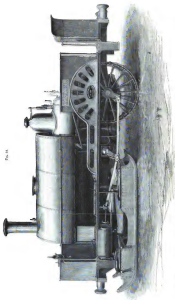


FIG. 14.

Locomotive Engine and tender as built, by Mr. E. Green, London. Cylinders 15 inches by 18 inches inside; upright wheels 4 feet diameter. (See page 11.)

coupled, 4 feet 3 inches diameter, in course of construction by Messrs. Cail & Co. This engine has Tenbrinck's fire-box, with 112 square feet of surface; the total heating surface amounts to 2,200 square feet. The wheel-base is 13 feet 4 inches. The engine will weigh 37 tons empty, and 43 tons in working order. The Southern Company (Compagnie du Midi) has adopted the same system of coupled wheels, with an ordinary fire-box.

A six-coupled wheel goods engine, made for the Orleans Railway, was exhibited jointly by Messrs. J. F. Cail & Co. and Messrs. Parent, Schaken, Caillet & Co. It has inside cylinders, with 5-foot wheels, and a wheel-base of 11 feet 4 inches. It had already run 13,000 miles on the central division of the railway, where the curves are numerous and sharp, and the inclines are steep. The fore and hind axle-boxes have $\frac{3}{4}$ inch play transversely, and are held taut by springs acting horizontally, which tend to restore them to their central position. The wheels are solid wrought-iron, of excellent workmanship, welded at two heats, on Arbel's system. The rim is forged in segments, the nave in two circular halves, and the spokes are let into the rim-segments, and the two halves of the nave. The whole are clamped together, heated together in a furnace, brought out and placed under a large hammer with suitable dies the size of the wheel, and welded on one side. The partially-formed wheel is again heated and welded complete on the other side. A first-rate piece of work can be done by this process; it requires six men and three labourers. The counterweights are welded to the rim and spokes of the wheels. The connecting and coupling rods are of cast-steel.

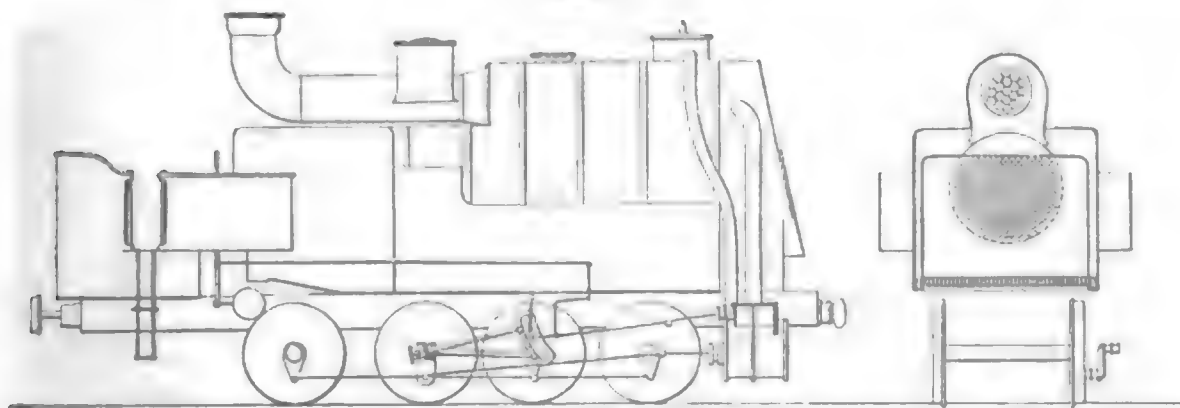
Three classes of locomotives are exhibited, actually and by drawings, by the Northern Railway Company of France, all of them special in design. The object which the engineers had

specially in view was to obtain a considerable supply of steam and great tractive power, in combination with the smallest possible weight. For this purpose, the fire-box on Belpaire's system is placed above the wheels and frame-plates, in order to afford greater width, a larger grate, and more tubes than when at the usual level, without lengthening the boiler. Eleven such engines are at work on the Northern Railway, burning coal-slack.

The roofs of the fire-box and its shell are flat and parallel, and stayed together like the sides. The steam-space in the barrel is reduced, to make room for the tubes, and is supplemented by a tubular steam-chamber above the boiler, made with iron flue-tubes $3\frac{1}{8}$ inches outside diameter, through which, and also round the steam-chamber, the heated gases travel for drying the steam. The chimney is laid horizontally in continuation of the envelope which surrounds the steam-chamber, as the great elevation of the boiler, about 8 feet from the rails to the centre of the barrel, prevents its being, if placed vertically, of sufficient length.

In arranging the passenger-locomotive for heavy gradients on this system, of which a drawing is exhibited, the ordinary coupling of wheels is dispensed with, and four $14\frac{1}{4}$ -inch cylinders with $13\frac{1}{4}$ inches stroke, and 5 feet 3 inch wheels on two independent axles are employed, one pair of cylinders and wheels at each end of the engine, with small intermediate carrying wheels, 3 feet 6 inches diameter; the whole on a wheel-base of 17 feet in length. The boiler weighs $12\frac{1}{2}$ tons, the whole engine 48 tons, comprising 7 tons of water and 2 tons of fuel, with a traction-weight of 21 tons. In determining the size of the driving wheels, the engineers have been guided by their experience of the larger wheels of their older stock; the $7\frac{1}{2}$ -foot driving wheels having been succeeded by $6\frac{1}{2}$ -foot wheels,

FIG. 17.



HEAVY-GRADIENT LOCOMOTIVE, on the Northern Railway of France; cylinders 18·9 inches diameter, 18·9 inches stroke; eight coupled wheels 3 feet 6 inches diameter; horizontal chimney and superheating chamber.

which they have found to work at least as well as the larger wheels.

In the designs of the goods engines, the whole weight has been utilized by coupled wheels:—First, in the heavy-gradient locomotive actually

exhibited, and, second, in a four-cylinder locomotive with six axles, coupled in two groups of three, of which a drawing was exhibited. The diameter of the wheels of the latter is 3 feet 6 inches, and, being twelve in number, they

occupy a wheel-base 19 feet 8 inches long, the fore and hind axleboxes having $1\frac{1}{4}$ inch lateral play, to admit of working on quick curves of 600 feet radius. The engine has 36 square feet of fire-grate, and 2,300 square feet of heating surface, having 464 flue-tubes, $1\frac{9}{16}$ inch in diameter. The cylinders are $16\frac{1}{2}$ inches diameter, $17\frac{1}{4}$ inches stroke. The gross weight is 41 tons empty, and 57 tons full, equally distributed, giving from 9 to 10 tons to each pair of wheels.

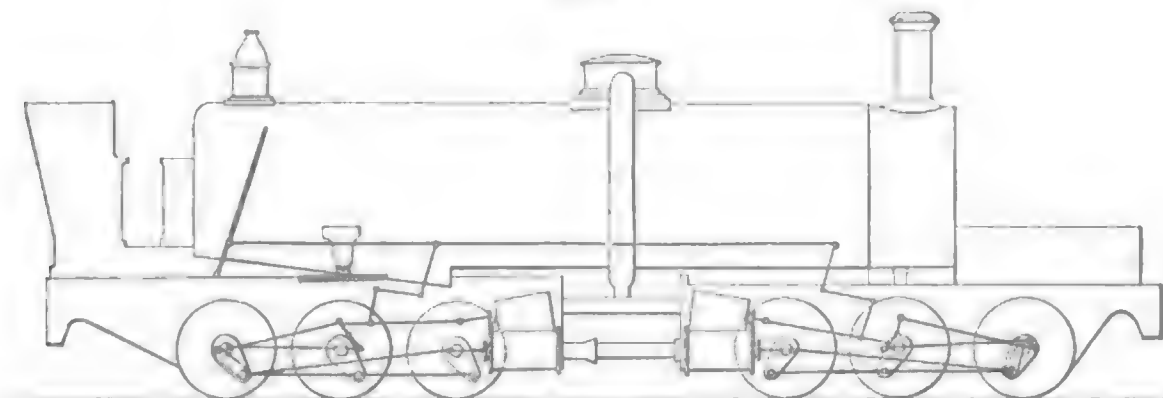
The "heavy-gradient" locomotive has eight wheels, 3 feet 6 inches diameter, on a base 12 feet 6 inches long; two cylinders 18.9 inches diameter, 18.9 inches stroke. It has 28 feet of grate, and a total heating surface of 1,800 square feet, having 356 flue-tubes, $1\frac{9}{16}$ inch diameter. The superheating chamber has 129 square feet of heating surface. The engine weighs, in working order, $42\frac{3}{4}$ tons, equally distributed, giving 10 to 11 tons weight per pair of wheels (fig. 17).

In all of the three kinds of engine exhibited by the Northern Railway Company, the cylinders are outside, and the valve-gearing outside them and overhung, which is, as already remarked, the most unfavourable position of gearing for continued accuracy of action. The weight is top-heavy, and, for a run of 230 miles, the length of the line, they cannot well be worked with safety at the occasional high speeds demanded by a large traffic on a long line. The exhibitors base their calculations of the capacity of engines on heating surface, as such, which they assume to be equivalent to evaporative power. It may be remarked that there is only $\frac{7}{16}$ inch clear space between the 356 flue-tubes of the "heavy-gradient" engines, and only $\frac{9}{16}$ inch between the 464 tubes of the four-cylinder goods engine—proportions utterly inadequate to maintain an effective circulation and evapo-

rating action on every unit of surface. Half the number of tubes properly placed would have answered the purpose decidedly better. The best thing about the engines is the uniform distribution of the weight, giving great tractive capacity without distressing the road on the straight portions; but the wheel-base is impracticably long in the four-cylinder engines, and must greatly strain the engine and road as well as add to the resistance on quick curves. The exhibitors have not presented any statement of the consumption of fuel by the engines, which must, from their construction, weight, and extensive wheel-base, be excessive. It may be stated, however, that the proportion of the tractive power (taking the effective mean pressure in the cylinders at 80 per cent., for low speeds, of the pressure in the boilers, 118 lb.) is about one-sixth of the weight for adhesion, which is a fair proportion, and utilizes the immense weight of the engines. M. Flachet, in his notice of the locomotives at the Exhibition,* states that the passenger engine is expected to take 15 carriages at 45 miles per hour, or 24 carriages at 30 miles per hour, up an incline of 1 in 200; and that the four-cylinder goods engine will take a load of 240 tons up an incline of 1 in 50. These expectations are moderate enough, and certainly they do not warrant such extraordinary and costly departures from the usual form of locomotive.

A model of an eight-coupled-wheel goods engine, designed by the late M. Polonceau, was exhibited by Madame Polonceau, the peculiarity of which is the use of an intermediate crank-shaft, carried by the frame, to receive and transmit the power by coupling-rods to the wheels, which are 4 feet 1 inch diameter, on a base of 13 feet. The heating surface is 2,200 square feet, and the weight, in working order, would be 42 tons.

Fig. 18.



ARTICULATED TANK-LOCOMOTIVE, by Messrs. J. J. & A. Meyer, Vienna; with four cylinders $17\frac{1}{4}$ inches diameter, $19\frac{1}{4}$ inches stroke; twelve coupled wheels, in two independent systems, 3 feet 10 inches diameter.

The designs of an "articulated tank-locomotive of great power"—like what is known in England as a bogie-engine, were exhibited in the French department by Messrs. J. J. & A. Meyer, of Vienna, of whom the senior partner is the inventor of the well-known variable-expansion

gear with which his name is associated. The engine has twelve wheels, all coupled, in two groups of six, with four cylinders, one pair to each group (fig. 18). The designers remark that on

* "Annales du Conservatoire Impérial des Arts et Métiers." December, 1862.

many railways an adhesion weight of 40 tons has become insufficient; that the necessity for constructing railways cheaply has led to the adoption of steep gradients and quick curves; that the engines adapted to work these lines must have, in certain cases, 50, 60, and 80 tons adhesion-weight, with the means of deflecting or suiting the engine to the curves; and, finally, they condemn the practice of assistant engines, and that of separating trains into two or more parts, in particular situations, as inconvenient and costly.

In the locomotive proposed by Messrs. Meyer, the boiler is carried on two distinct and independent frames of three axles and six coupled wheels, with a pair of cylinders to each. The water-tanks are in front, the coal-boxes behind, and the distribution of weight on the two frames is such that the centre of gravity of each load is above the centre axle. The boiler rests on the front frame, by a ball-and-socket pivot at the centre, over the middle axle; and on the back frame by two semi-spherical bearings on the frame, one on each side of the fire-box:—resting thus on three points, whilst the front frame, or steam-bogie as it may be called, is free, by swivelling under the boiler, to follow the curves and irregularities of the road. The semi-spherical bearings at the sides of the fire-box have a limited play fore and aft, to suit the changing position of the boiler. The whole of the cylinders, valves, and other mechanism, are outside the wheels. The whole weight, 60 tons, is available for adhesion, 10 tons per axle. Each frame stands on a wheel-base of 8 feet 6 inches, and the centres of the frames are 22 feet apart. The wheels are 3 feet 10 inches diameter; the cylinders are 17½ inches diameter, 19½ inches stroke. The tractive force is estimated at 22,000 lb., one-sixth of the weight, to take a gross weight, including the engine, of 2,300 tons on a level at 10 miles per hour; 340 tons up an incline of 1 in 40; and 155 tons up 1 in 17 (fig. 18).

Messrs. Meyer call their system "the universal system," as it admits of extension and adaptation. They have designed an express engine with four cylinders and twelve wheels, of which one pair are drivers; a mixed engine with four cylinders and twelve wheels, and two pairs are drivers; a goods engine with four cylinders and sixteen coupled wheels in two frames; another with six cylinders and eighteen coupled wheels in three frames; and an engine with eight cylinders and twenty-four coupled wheels, in four frames.

This system of Messrs. Meyer, which they have so ably designed, affords unquestionably the most satisfactory solution of the problem of maximum-power goods engines. With independent steam-driven swivelling frames, they get rid of a mass of coupling-rods and parallel motions, by which the resistance of the engine is materially reduced in its working parts, and in passing along curves leaving a balance of power for useful work.

BELGIUM.—There was but one locomotive from Belgium,—a six-coupled-wheel inside-cylinder engine, made and exhibited by the "Société Anonyme" of Couillet for the Belgian State Railway, to the designs of M. Belpaire, engineer-in-chief of the railway. The fire-box is on M. Belpaire's system, a reproduction of Mr. Cudworth's, with a long inclined grate, but wanting the longitudinal partition. The fire-box affords the same advantages as Mr. Cudworth's, in admitting the hind axle below it, giving a moderate wheel-base, in this instance 13 feet 1 inch, and equalising the distribution of the load on the wheels, which is as follows:—

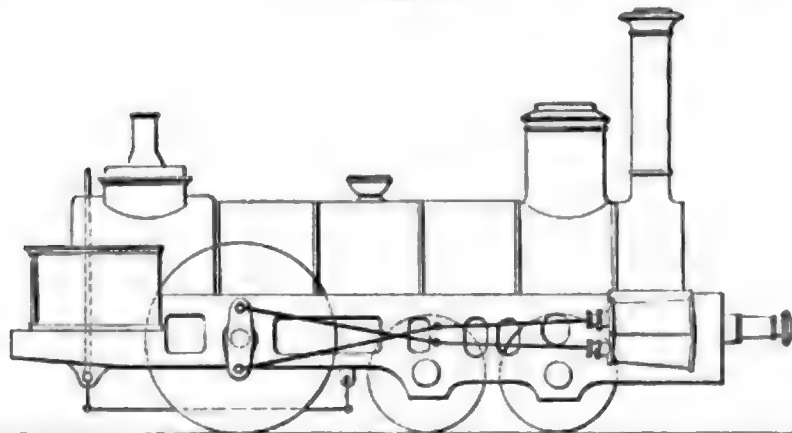
		Tons cwt.
Leading Wheels	.....	11 0
Middle do.	.....	11 9
Hind do.	.....	11 0
TOTAL		33 9

But the connection of the machinery and framing is radically defective. The three axles have each two outside bearings, carried by two single outside frame-plates, and the cranked axle has only one additional bearing, 4½ inches long, placed in the centre, between the cranks. This single narrow bearing, compressed between the two cranks, is exposed to and must receive the entire fore and aft strain of the steam-pressure; whilst the outside bearings, 7 inches long, are more than 6 feet apart, and in consequence of the elasticity of the cranked axle, receive very little of the fore and aft thrust and pull. But the middle bearing must ultimately wear loose, and the whole of this strain will be thrown upon the outer bearings, at 6 feet centres, in addition to the strain arising from the loads on the bearings outside, which will of course break the axle. Again, the fastening of the cylinders to the frame is effected through the valve-chests, which are exterior to the cylinders, in two castings, spanning, likewise, a space of 6 feet between the plates,—a disposition which, unless the cylinder castings are made exceedingly strong and heavy, will also overstrain and break the connections. On the contrary, by devoting, in this engine, the space on the cranked axle usually occupied by the inside bearings, to the valve-gear and eccentrics, the valve-motion is very conveniently accommodated, and probably this slight advantage was the inducement to depart from the usual and indispensable application of well-proportioned and substantially constructed inside bearings at the wheels.

AUSTRIA.—*The States Railway Company.*—Two engines were exhibited from this railway; of which the first is a passenger engine, the "Duplex," with four cylinders and four cranks on a single driving axle, specially designed for steady running at high speeds. Mr. Haswell, the engineer, and designer, supersedes the usual counter-weights in the driving wheels, and causes the

reciprocating and working parts to balance each other by placing a pair of cylinders side by side and connecting them to a crank and return-crank opposed to each other on each side of the engine, so that the pistons on each side and all their connections move in contrary directions and

FIG. 19.



SELF-BALANCED EXPRESS LOCOMOTIVE, the "DUPLEX," by Mr. Haswell, on the Austrian States Railway, with two pairs of cylinders 10 $\frac{1}{2}$ inches diameter, 24 $\frac{1}{2}$ inches stroke, and one pair of driving wheels 6 feet 9 inches diameter.

balance the inertia of each other. The cylinders are 10 $\frac{1}{2}$ inches diameter, with 24 $\frac{1}{2}$ inches stroke, and 6 feet 9 inch driving wheels. There can be no question that the system is perfectly successful in effecting the object in view; and had it been brought out twenty years ago it would have been highly appreciated. But the system is not likely to become popular, as the equilibration of engines is, and has been for ten years, completely accomplished, for practical purposes, by means of counterweights, with two cylinders; unless, indeed, railway companies, in the race of competition, should aim at speeds of 80 or 100 miles per hour (fig. 19).

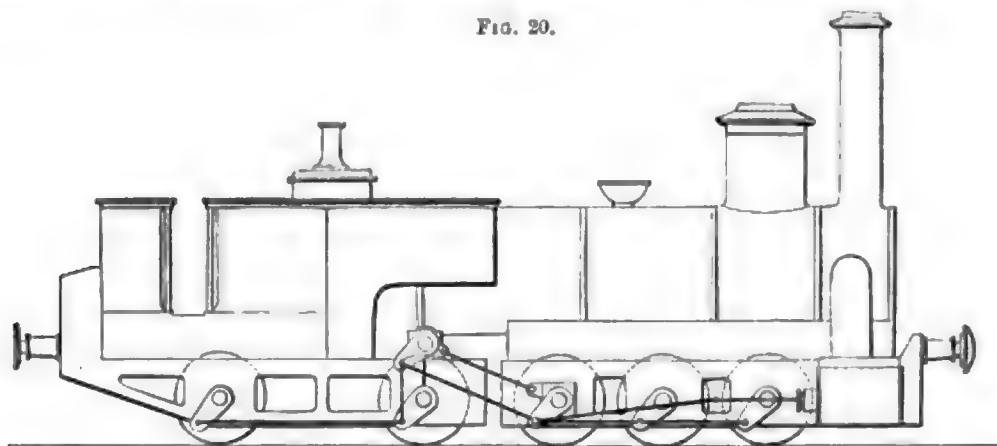
The other engine, the "Steierdorf," is a tank-engine of the Engerth system, with five-coupled axles. The boiler rests on two frames, coupled together by a pivot-bolt. The steam

cylinders are fixed on the fore part, the tank on the hind part, and the wheels on the fore frame are coupled with those of the hind frame by means of an intermediate shaft and radiating parallel-motion, ingeniously contrived to adapt itself to the varying angularity of the hind frame on curves, and at the same time to continue to transmit the power from the first to the second frame. This plan of connection has been designed to supersede Engerth's mode of coupling the axles by spur wheels. The intermediate shaft was proposed in 1852 by Mr. Kirchweger, and the application, as exhibited, was worked out by Mr. Pius Fink. The intermediate shaft has overhung cranks, and is carried above and by the fore axle of the tender on spherical bearings; and it is connected to, and at a proper distance apart

from, the hind axle of the engine, by rods, also with spherical bearings. The relative positions of the three axles being thus fixed, the power is transmitted from the hind or driving axle of the engine, by coupling-rods, to intermediate cranks, and thence to the outside cranks of the fore tender-axle, and further by coupling-rods to the hind-axle. The wheels are 3 feet 3 $\frac{1}{2}$ inches diameter, the cylinders 18 $\frac{1}{2}$ inches by 24 $\frac{1}{2}$ inches. The total weight in working order 46 tons. The fire-box, made for burning coke, has 15 square feet of grate, and, with great good sense and reticence, there are introduced only 158 flue-tubes 2 $\frac{1}{4}$ inches diameter, with plenty of clear space between them (fig. 20).

Herz.—A drawing is exhibited of a small tank-locomotive, by Dr. Herz, which he calls "an

FIG. 20.



ARTICULATED TANK-LOCOMOTIVE, the "STEIERDORF," by Mr. Haswell, on the Austrian States Railway; with one pair of cylinders 18 $\frac{1}{2}$ inches diameter, 24 $\frac{1}{2}$ inches stroke, and ten coupled wheels 3 feet 3 $\frac{1}{2}$ inches diameter.

economical locomotive," in which there is nothing further to remark.

PRUSSIA.—*Borsig*.—There is only one engine from Prussia, exhibited by Mr. A. Borsig. It is

a six-wheel four-coupled engine, with outside cylinders 17 inches by 22 inches, and driving wheels of 4 feet 6 inches, the hind wheels being coupled, and all the axles being between the fire-box and smoke-box. This type of engine is

exclusively employed on the Minden and Cologne Railway, for mixed and goods trains. It is employed also on many other German railways. The free use of steel in the construction of this engine confers upon it an air of lightness, perhaps too great lightness, which contrasts strangely with the heaviness of the tender. The proportions of the boiler are good, and this, in addition to the very excellent and well-finished work, may account for the popularity of this class of engine; but there are grave defects about it which much detract from its usefulness. The suspended weight is placed on three points by a cross spring over the fore axle, and equalising levers or beams connecting on each side the coupled-axle springs. This notion of a triangular bearing, with the apex in front—much made of at one time,—is now nearly discarded in England, giving the engine a dangerous freedom of movement at high speeds. The cylinders are fitted with double valves similar to Bodmer's old valve for variable expansion, the expansion-valve being on the back of the other, with a central passage for steam through it; the lower or leading valve is worked by a link-motion in the usual manner, and the upper valve by a separate rod from the fore eccentric, working in a grooved sector similar to Hawthorn's old motion, from which a variable travel and cut-off are communicated to the valve. The steam-port opens for the exhaust at nine-tenths of the stroke, for all degrees of expansion, and is only opened $\frac{3}{8}$ inch for the exhaust when the piston arrives at the end of the stroke. As the steam-ports are only 9 inches long by $1\frac{1}{4}$ inch wide, having a sectional area of $11\frac{1}{4}$ square inches, or only one-twentieth of that of the piston, it is obvious in the first place that they are too small for the escape of exhaust steam, and that a considerable degree of back pressure on the piston must act on the piston at working speeds, even if the port were full open for exhaust at the end of the stroke. But, as it is only $\frac{3}{8}$ inch open at this point, there can be no doubt the back pressure is seriously increased in consequence; and more particularly with an outside cooling cylinder. For a $17\frac{1}{4}$ -inch outside cylinder, in Neilson's engine, a steam-port is provided, 13 inches long by $1\frac{1}{2}$ inch wide, having 21 square inches of sectional area, one-eleventh of that of the piston; his valve, moreover, is open full port for the exhaust, when the piston reaches the end of the stroke. Further, it is not good practice to fix the same point of the stroke for the exhaust under all degrees of expansion; high expansive-working is usually practised at high speeds, and therefore the exhaust should be appointed to open earlier in the course of the stroke, for the higher grades of cut-off and expansion, in order to give the steam greater liberty for escape before the piston returns upon it. These conditions of the good working of steam are comprehended in Stephenson's expansion-link motion, and are now

thoroughly appreciated and established in English practice. Borsig's or Bodmer's valve came out when everybody, twenty years ago, was scheming a new expansion-valve motion that would rival or supersede the link-motion, which has not yet been accomplished.

In employing cast-steel for the working parts of his engine, as the piston-rods, the connecting and coupling rods, and the crank-pins, Mr. Borsig has reduced, in some cases, the dimensions of the wearing surfaces. The bearings of the coupling-rods are reduced, in fact, in proportion to the size of the rods; though it is reasonable that, as the strains remain the same, the sizes of the wearing surfaces should not be altered. The axle-boxes are of wrought-iron.

SAXONY. — *Hartmann.* — Mr. Hartmann, of Chemnitz, exhibited a six-wheel four-coupled engine, specially designed to work in mountainous districts. It is, in fact, a bogie-engine, having four coupled wheels, 4 feet 6 inches diameter, with 21 tons on them for adhesion, and a swivelling truck, like Bissell's, in front, with 7 tons, making a total of 28 tons. The cylinders are 15 inches by 22 inches stroke, and are outside, with outside valve-gearing, as is fashionable on the continent. The framing has two longitudinal plates, 8 inches deep, $1\frac{1}{2}$ inch thick, from which the cylinders depend, with 16 inches of overhang. This is an excessive overhang upon so narrow a base-plate, and, the valve-gear being still further overhung, the valve is shaken at every stroke, as the axle-boxes wear loose. Overhung eccentrics and valve-gear, outside the crank-pin, never do well for heavy work, in consequence of their unsteadiness in that situation. The best feature in this engine is the swivelling truck, with a triangular frame, which carries the fore part of the engine on one pair of wheels, with a limited but sufficient allowance of lateral play, and radiates on a pivot behind it, fixed under the boiler. With a flexible wheel-base, only 11 feet 9 inches long, there is no doubt that in this, and in engines of ordinary size, the Bissell truck is well adapted for leading them round the quickest curves likely to be found in practice.

ITALY. — *Pietrarsa Royal Works, Naples.* — An inside-cylinder six-coupled locomotive is exhibited, of the old school, creditable to the rising genius of Italy.

M. T. Agudio, of Turin, exhibited a model of a traction-carriage for moving heavy trains along steep inclines by means of ropes. He uses two, instead of a single wire rope, whereby he expects to obtain considerable economy over the ordinary endless-rope system, and to make the apparatus safer and more certain and effective in its action. "It is proposed to attach a traction frame or carriage, mounted upon two four-wheeled bogies, at the front and rear ends. The centre portion of this frame carries two shafts, each provided with a fast and loose grooved pulley or drum. A

strong flat wire rope is passed round the two fast drums, and guided on to them by the loose pulleys. It is fixed at the upper extremity, and kept distended by a heavy weight at the lower end of the inclined plane. In order to communicate motion to the two fast drums, an endless slender wire rope is carried throughout the length of the incline; the ascending side of this endless rope is passed round a grooved pulley fixed on the end of one of the drum-shafts, and the descending side of the same rope is passed round a grooved pulley fixed on the end of a central shaft situate between, and parallel to, the two drum-shafts. This central shaft carries a friction-wheel or pinion, which imparts motion to two larger friction-wheels, respectively keyed on to the two drum-shafts, and bearing upon opposite sides of the circumference of the central friction-wheel or pinion, against which they are forcibly held by the tension of the flat hauling wire rope passing round the two drums. When the endless wire rope is set in motion by means of a fixed engine at the top or bottom of the incline, or by both, motion is imparted to the two drums, and these act upon the flat wire rope, and thus haul the train up the incline. The dimensions of the drums and pulleys admit of the endless rope travelling at about double the speed of the train; and by the simultaneous combined action of the ascending and descending sides of the endless rope on the pulleys, it is only subjected to about one-fourth of the strain it would have to bear under the ordinary system, where a train is hauled directly by the single ascending side of the endless rope attached to the train, without the intervention of any pulleys. A break is fixed on the carriage to prevent accidents, in the event of a rope breaking; and by using separate fixed engines for the ascending and descending sides of the endless rope, it is thought that if one of the engines should be disabled, the other could still be worked; and thus the traffic on the line need not be stopped."

CHAPTER V.

CONCLUDING CHAPTER ON LOCOMOTIVES.

It appears that the exigencies of continental railway traffic have demanded a greater variety of locomotive engines than have been found necessary in the United Kingdom. Trains on the continent are heavier, speeds are lower, and, more than all, inclines are steeper. Whilst, then, the marks of progress in English engines are to be found mainly in refinements upon the normal types, foreign engineers have discarded our traditional types, and have specialised in more than one direction. In England, engineers have arrived at higher speeds, with more powerful boilers and increased driving or adhesion-weight. The means of satisfactorily balancing the reciprocating and revolv-

ing machinery, theretofore the bane of the outside-cylinder engine, by counterweighting the wheels and steadying the engine, having been discovered and carried into practice since 1851, so that the outside-cylinder engine, properly balanced, runs even more steadily than the inside-cylinder engine, locomotists have employed outside-cylinders for high speed and other duty with complete success. Outside cylinders have not, however, been employed for the heaviest work. The inside cylinder is retained for the six-coupled goods-engine, and it is not likely to give way to the outside cylinder for that class of work. But for passenger-traffic, with four-coupled wheels, and the lighter traffic of collieries, and other private establishments, the outside cylinder is well suited, and is extensively applied. It is, however, to be explained that the advantage of the six-coupled engine is limited to the old and the comparatively straight lines of railway, on which the destruction of cranked axles is not rapid, and the wear and tear of tires not severe. For lines with prevalent curves, the four-coupled outside-cylinder engine surpasses in efficiency and economy the six-coupled,—running on curves with greater facility, utilising the adhesion-weight better, and being subject to less tear and wear. Hence the six-coupled engine, with inside cylinders, is to be found chiefly on the Southern and North-Eastern Divisions of the London and North-Western Railway, the Great Western, the Midland, the South-Eastern, the London, Brighton, and South Coast, the Great Northern, the North-Eastern, and the Edinburgh and Glasgow Railways—in short, the older and straighter lines (the Great Northern, though a newer, is one of the straighter lines). On the contrary, the outside cylinder, with single, and with four-coupled wheels, are to be found on the Northern Division of the London and North-Western Railway, the Lancaster and Carlisle, Caledonian, Scottish Central, Scottish North-Eastern, and Great North of Scotland, which are newer lines, and have many quick curves. The London and South-Western, and the Great Eastern Railways, it is true, are of the older and straighter class, and are stocked, or being stocked, with outside-cylinder engines and their correlatives, straight axles; but the former line was initiated with outside cylinders by the great apostle of straight axles, Joseph Locke, who was the engineer-in-chief of the line, and who imported his experience of the broken and short-lived cranked axles, and the durability of the straight axles on the original Grand Junction (London and North-Western Railway, Northern Division), and resolved, like a man of sense and experience, when he had a good thing, to keep it. The Eastern Counties, again, was originally stocked with inside cylinder engines; but the engines having passed into the care of Mr. J. V. Gooch, who brought from the London and South-Western Railway his experience of outside cylinders, the stock received

an infusion of outside-cylinder passenger engines; and having, at a later period, been placed under the care of Mr. R. Sinclair, who brought with him likewise his experience of outside cylinders—first, from the Paris and Rouen Railway, with Mr. Buddicom; secondly, from the Caledonian Railway, as chief engineer and locomotist;—the stock of the Great Eastern received an additional infusion of outside cylinders—mostly with four-coupled wheels, no six-coupled wheels. A prominent exception amongst the newer and more sinuous lines is the North British Railway, where inside cylinders have been universal; but they were introduced by the chief engineer, who was also the engineer-in-chief of the Edinburgh and Glasgow Railway—a first-class line for directness and flatness—where inside cylinders had answered perfectly well. It has nevertheless been found that, on that railway—the North British—the wear of six-coupled engines is excessive; that the wear of four-coupled engines is much less; and that the latter do more work with more ease and less cost of maintenance; and, doubtless, the outside cylinder and straight axle will find their way on that line.

In England, engineers have avoided the use of more than six coupled wheels in one engine; they know that three wheels coupled in one line are sufficiently powerful and sufficiently troublesome; and they prefer to supplement the power, when necessary, with an additional engine. On the continent, great efforts have, on the contrary, been made to construct an efficient engine with great tractive force, and enormous weight for adhesion, to ascend the long and heavy inclines peculiar to mountainous districts. The subdivision and placing of the weight in moderate loads on the rails have been effected with ease by distributing it over a sufficient number of wheels and axles. But the most important problem has been to reconcile the unavoidable extension of wheel-base, in a straight line, with the excessive curvature of the railways; for naturally, though unfortunately, heavy gradients and quick curves are in general to be found in company.

The system adopted on the Northern Railway of France, already described, must fail to answer the requirements, as, with a wheel-base so extended, the resistance of the engine itself must absorb a great proportion of the tractive power. A flexible wheel-base is indispensable, and unquestionably two ordinary engines connected together would operate much more efficiently and economically than the vast masses actually employed. The arguments of the engineers of the Great Northern of France against the use of coupling-rods for the wheels of passenger-engines, and the consequent proposal to substitute two independent pairs of driving wheels with independent cylinders must appear to be trivial, for in another class of their engines,—the “heavy gradient,”—eight wheels are coupled

on four axles. The truth is, for working four driving wheels, one pair of cylinders with coupling-rods is the best method of providing adhesion-weight, more especially as by the use of steel in tires their excessive and unequal wear and straining are to a great extent prevented. At all events, the wear may be regulated and equalized, which removes the only objection worth consideration.

The Austrian system of coupling over an extensive wheel-base, by a self-acting radial adjustment, in the “Steierdorf” (fig. 20), is a decidedly better plan, and it merits a thorough trial. There is nevertheless a complication of mechanism, with many rubbing surfaces and spherical joints, liable to occasional overstraining in transmitting the power over a long distance through a flexible connection; and engineers must look in another direction for a comprehensive and satisfactory solution of the problem.

The system of Messrs. Meyer (fig. 18), appears to be the best yet brought forward for distributing steam-power over a flexible train of coupled wheels. It is based on sound principles, as experience will no doubt prove. It is known that practically a locomotive-boiler delivers a better supply of steam to a given pair of cylinders fully worked at a low speed, than at a high speed, with ordinary management. The steam blows off, and there is plenty to spare. By making the boiler a little larger, then, Messrs. Meyer justly reckon that they can supply steam for four cylinders at a low speed, as well as for two, and they therefore divide the train of wheels into two independent groups under the boiler, each group free to adapt itself to the line of rails, and fitted with a pair of cylinders and the necessary coupling-rods, with a separate supply of steam. In short, they employ two steam-bogies, which carry the boiler and its accessories on their backs, like a load of timber on a couple of swivelling timber-trucks.

Locomotive engineers, particularly foreign engineers, appear to have overrated the abstract value of heating surface. Scarcely alive to the great importance of free passage for currents of water in intimate contact with the heating surface, whether of the fire-box or of the tubes, many engineers have reduced the width of the water-spaces around the fire-box to a minimum barely sufficient to preserve the plates from being over-heated; they have likewise placed the flue-tubes so near to each other, and in such large numbers, as to defeat their object of increasing the steam-producing power of the boilers, because they have rendered it impossible for the water, crowded the surface with struggling globules of steam, to reach the surface of each tube, and to be evaporated. Tube-surface under such circumstances is inactive, and ultimately becomes mischievous, for the sediment deposited by water in boilers will, if not scoured out, coat the tubes and block up the

interspaces altogether. The greatest number of tubes known to have been applied in England are the 305 tubes of the Great Western express engines of the class of "The Lord of the Isles," exhibited in 1851. In these the tubes, 2 inches diameter, are placed only $\frac{1}{4}$ inch apart, and are not so effective for evaporation as the tubes of earlier engines on that line, which were fewer in number, but were placed at from $\frac{1}{2}$ to 1 inch clear.* In the English engines exhibited in 1862, the greatest number of tubes was 215, by Messrs. Beyer, Peacock & Co., $\frac{9}{16}$ inch clear; and the North-Western Company applied 214 at $\frac{1}{4}$ inch clearance. The best English practice exhibited is to be found in the North-Western engine, "The Lady of the Lake;" Mr. Connor's engine, by Messrs. Neilson & Co., and Mr. Sinclair's engine; all of which, singularly enough, have identically the same proportion—192 tubes, $1\frac{1}{2}$ inch diameter, $\frac{1}{2}$ inch clear, placed in a barrel 3 feet 10 inches inside diameter. The goodness of these proportions is proved by the very satisfactory performances of the engines, under very different circumstances. The greatest number of tubes exhibited in the foreign engines is 356 tubes, with $\frac{7}{8}$ inch clearance, in the heavy-gradient engines on the Northern Railway of France. The drawings further exhibit the 12-wheeled goods engine with 464 tubes, having $\frac{9}{16}$ inch clearance. These proportions will disappoint the expectations of the projector; and the experience of a few years will, it is presumed, modify the extreme views about heating surface entertained on the continent.

The distinction between fire-boxes for burning coal and those for burning coal-slack should not be overlooked. For coal, 13 to 15 square feet of grate is sufficient; for slack, the North-Western Company provides 25 feet of grate, and Messrs. Sharp, Stewart & Co., $27\frac{1}{2}$ feet. The difference of fuel leads to a difference of treatment, inasmuch as special provision is made for the admission of air above coal in burning, in addition to that which passes through the grate. For slack, no such provision is practised; the layer of fresh fuel is thin, and a sufficient quantity of air is drawn through the large surface of grate; at the same time, the fuel is charged in smaller quantities, and much more frequently, than coal in lumps.

In their modes of placing the machinery on the frame, continental engineers have shown how an inferior thing can be made to do. Next to heating surface, their partiality is observable for overhung valve-gearing upon outside cylinders,—in the most unfavourable position for efficiency and handiness of engine.

Giffard's injectors have been extensively employed as a substitute for the ordinary feed pumps, and the general adoption of them by

locomotive engineers in England and on the continent, is an evidence of their popularity and general efficiency. The only apparent objection to the use of the injector is its inability to deliver heated water at more than 120° Fahrenheit of temperature, as it prevents the use of means for heating the feed water by the contact or mixture of the water with the exhaust steam; though it may be used with surface-heaters. The injector, as all the world knows, acts by the force of a jet of steam from the boiler, delivered into a conical orifice, drawing or sucking with it a current of feed-water into the orifice. The water condenses the steam, and the resulting mass of heated water, in virtue of the velocity of the steam-element now imparted to the mass, forces its way through the delivery valve into the boiler. The invention is very ingenious and is most creditable to the inventor; and is not the less so, that it is paradoxical,—an inferior pressure apparently overpowering a greater:—steam from the boiler describing a circuit, and forcing its way back again. The injector operates independently of the speed of the engine, and acts when the engine is at rest, thus superseding the donkey-engine. A notice of the injector will be found with the description of the machine-tools exhibited by Messrs. Sharp, Stewart, & Co.

CHAPTER VI.

RAILWAY CARRIAGES AND WAGGONS.

The classification of Railway Carriages is designed to meet the various requirements of the travelling public: some preferring ease, seclusion, luxury, high speed; others preferring society, if tolerable, and economy, with moderate comfort and moderate speed; others looking to economy simply. For the sake of uniformity externally, and in many of the details, carriages are usually made of the same general dimensions. The attainment of uniformity of waggons is more important than that of carriages, as their total number and cost are much greater, and supervision is less minute. One of the greatest engineering evils that has been inflicted upon railway companies has arisen from the want of arrangement or consultation between the officers of different lines, in order to consider the question, common to all, of the best plan and construction of vehicles to be used by them. The result has been, that several companies have built classes of stock unsuited to work conjointly the traffic of their own and other lines. Diversity of practice has no doubt been partly occasioned by the growing wants of traffic, and the gradual increase in capacity and tonnage of the carrying stock, incurring unavoidable structural alteration. Amongst the early contributors to the production of the railway waggon were to be found the great carriers, their agents, road-

* For an experimental investigation of this important subject, see the Author's work on "Railway Machinery," pages 157 and 158.

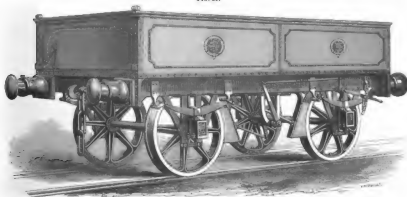
contractors, farmers, builders, wheelwrights, salesmen, graziers, timber-merchants, and whose occupations and opinions, it may be imagined, gave birth to a wide diversity of practice. Another reason for the want of harmony in past practice has been the separation of the duties of engine superintendence from those of carriage and waggon superintendence. The carriage superintendent, aiming at the utmost economy of maintenance in his department, has been continually adding to the quantity and weight of material used in the construction of the carrying stock, to remedy the failures of weak parts; and thus the stock—waggons particularly—has been increased in strength, rather by adding to the mass of matter than by studying to throw the same weight of timber and iron into superior combination. Doubtless, the stock was made more lasting and serviceable, but meantime the heavy trains, handed over to the locomotive department, induced similarly the construction of heavier and more powerful locomotives, when the maximum was quickly reached, and strongly evinced by the sufferings of the permanent way.

It was, of course, unavoidable, from the need of enlarged dimensions and capacity, and increased strength, both in carriages and waggons, that the dead weight should be to some extent increased. The early first-class carriages weighed $3\frac{1}{2}$ tons, the bodies or upper parts being 15 feet long, $6\frac{1}{2}$ feet wide, and 4 feet 9 inches high, in three compartments, to hold six passengers each, or eighteen in all. The compartments were finished, internally and externally, precisely like the bodies of stage-coaches, and were made to appear like three bodies placed side by side upon one underframe. To this day the same

appearance is maintained by means of the quarter-mouldings; and it is a question for the historian, whether the desire of the early railway-carriage builders to provide repeated likenesses of the old coach has not powerfully influenced the course of subsequent practice, and that it has not in some degree created the prevalent taste for exclusiveness and separation amongst railway travellers. Railway carriages have been gradually increased in weight to from $5\frac{1}{2}$ and $6\frac{1}{2}$ tons; and in the size of the body to 18 or 20 feet long, $7\frac{1}{2}$ feet wide, and 6 feet 3 inches high. The great increase in size and weight of carriages has arisen very much in compliance with the demands of the public for greater convenience, speed, and safety. It was found that the old carriages suffered the most in cases of collision, and it became essential, with the increase of speed and length of trains, to add very much to the size, strength, and weight of railway carriages.

The original form of goods waggons generally employed for some years after the opening of the Liverpool and Manchester Railway in 1829, was simply a platform about 10 feet long, on four wheels, with sides varying from 4 to 10 inches in height, weighing $2\frac{1}{2}$ to $3\frac{1}{2}$ tons, and carrying 2 tons of goods. Many of these waggons are still employed for the transport of weighty rough goods. The general unsuitableness of this style of waggon led to the adoption of portable sides and ends, which consisted of open crib-rails dropped into staples; and to these were added the costly tarpauling or sheet, to cover the goods and bind them down, making a waggon 13 or 14 feet long, weighing $3\frac{1}{2}$ tons, fitted to carry 4 or 5 tons of ordinary

FIG. 21.



OPEN WAGON, by the Gloucester Waggon Company; having a sheet-iron body and iron underframe.

goods. But loose or moveable parts of waggons are objectionable; the use of tarpaulings amounted to an annual charge of £12,000 on one railway. Built covered waggons have to a considerable

extent superseded the crib-rail and tarpauling, having sliding doors and a moveable roof; so that the crane-chain can deposit or move a bale of goods, however heavy, from any part of the

interior of the waggon, and the goods may be perfectly enclosed. Mr. H. H. Henson exhibited a waggon of this description in 1851. It may be stated, generally, that properly-made open waggons may carry twice their own weight of goods, and covered waggons one and a half times their own weight. Examples of both kinds of waggons were exhibited in 1862. Messrs. Harrison and Camm exhibited a coal-waggon 13 feet long and 7 feet 4 inches wide outside, of massive proportions, with dead buffers and dead draw-hooks, on the usual Midland type, weighing 4 tons 6 cwt., and made to carry 7 tons. The great weight of waggons, it may be remarked, has arisen very much from the absence of spring-buffers at the ends, and the imperative need of strength and stiffness to resist the inevitable hard concussions to which they are subject in daily use. To reduce the violence of such concussions, and also not to add very much to the cost of the waggon, buffing-springs were applied at one end of each waggon, leaving the other end dead. The benefits of even this partial arrangement became evident; and several forms of external buffers—compact, efficient, cheap, and easily applied—have been matured. Spring-buffers are now generally applied to both ends of waggons.

The Gloucester Waggon Company exhibited an open waggon, built altogether of iron, 14 feet long, 7 feet wide, and 2 feet 4 inches deep. This waggon is solidly constructed of sheet iron; it has spring buffers at both ends; and it weighs 4 tons, and carries 8 tons,—twice its own weight. Waggon underframes made of iron have been in use on the Great Western Railway for many years, with great advantage in economy of maintenance. They have been tried on narrow gauge lines also, but generally, if not always, with dead buffers; and the severity of the concussions attending the use of solid ends may perhaps account for the partial abandonment, on narrow gauge lines, of this kind of framing (fig. 21).

Mr. John Ashbury, of Manchester, exhibited a covered goods-waggon, 16 feet long by 8 feet wide, with double sliding doors on each side, and 3½ feet solid wrought iron wheels. The framing was of teak,—an exceedingly hard and solid wood,—and the floor, lining, and roof, of deal boards. This waggon was built from the raw materials, of timber and pig iron, in 11 hours and 20 minutes, and of unexceptionable workmanship,—a performance, in point of time, hitherto unmatched as a *tour de force*. A few particulars of the performance may be interesting:—the whole of the timber for the waggon, consisting of 305 pieces, was cut out of the logs and the deals in 2 hours and 9 minutes. The planing, mortising, tenoning, &c., was done by machinery in 2 hours 46 minutes. The waggon was put together, including the fixing of all the iron work, painted, and varnished, by the united labour of 38 carpenters, in 257½ hours collectively.

In the forge, the whole of the iron was made

from pig iron: 79 bars were required, of thirty different sizes; and in addition, the wheel-iron bars and forging for spokes were made—weighing in all, 3½ tons nett; with the labour of 111 men and boys working collectively 368 hours 35 minutes.

In the smithy, 342 bolts and nuts were forged and screwed by 38 men and boys, working collectively 41½ hours. The wrought-iron work for the body of the waggon, exclusive of wheels and axles, and bolts and nuts, numbered 171 pieces, and was completed by 78 men working 118 hours.

In the turning-shop, the turning, boring, fitting, and finishing of the two pairs of wheels and axles, was done by 63 men and boys working 31 hours 34 minutes. The buffer bars with solid forged heads, with all the small work, were turned and fitted by 4 boys in 2½ collective hours. In the foundry, 32 castings were completed by 6 men and 3 boys working 10½ hours. In the fitting-shop, the axle-boxes, &c., were completed, and 522 holes drilled, and with the remaining work, occupied 71 men and boys 177½ hours. The waggon complete weighed 4½ tons, and would carry 7 to 8 tons of goods. Economists may find in this *résumé* materials for a comparison between the cost of highly-organized forced labour, and that of regular labour.

Mr. Ashbury exhibited a well-built saloon-carriage with tables, finished in good taste. The body of the carriage is 27 feet long, and 8 feet 4½ inches wide, built of teak; the panels showing a beautiful natural grain of wood picked out with gilt lines. The under-frame is also of teak, with buffer-rods and laminated buffer-springs. The carriage is divided internally into four compartments, communicating by sliding doors—namely, ladies' or invalid's compartment, principal saloon, water-closet and lavatory, and smoking saloon. A water cistern is provided on the top. The ladies' compartment is fitted with a handsome sofa, made to draw out, so as to make a bed; it has a water-closet in one corner, with a lid and silk cushion to form a seat, with a seat in the opposite corner; there are two mirrors, one on each side of the doorway. The principal saloon is 13 feet long, and 7 feet 9 inches wide inside, with four handsome sofas and two tables, and four mirrors. The smoking saloon is fitted with comfortable lounges. The floor is richly carpeted. As a carriage for long journeys, this one leaves nothing to be desired. Its weight amounted to nearly 9 tons, its value to £1,000; it had accommodation for 24 passengers.

Messrs. J. Wright & Sons exhibited a first-class carriage, constructed for the Egyptian Railway. The body is 19 feet long, 8 feet wide, and 6 feet 3 inches high at the side. The framework is entirely of teak, and the panels of papier maché: these materials have been found well suited for hot climates. The body is divided in the usual manner into three compartments. The interiors are trimmed with drab morocco and silk

lace. The seats and backs are stuffed on springs with horse-hair. To increase the facilities for ventilation, the windows in the quarters, as well as those in the doors, are made to fall with balance-weights. In addition, there are Venetian blinds, and moveable ventilators above the windows, protected from dust by copper-wire gauze on the outside; also two ventilators in the roof of each compartment, which may be adjusted to direct a current of air into the carriage going either way. There is a duplicate roof 10 inches above the lower one, to throw off the direct rays of the sun.

The under frame is constructed entirely of angle and T iron, riveted together. The wheels are in two pairs, of solid wrought-iron, 3 feet 6 inches diameter, with Beattie's fastenings to secure the tires. Beattie's axle-boxes also are used, adapted for using either oil or grease. The weight of the carriage is $7\frac{3}{4}$ tons.

FRANCE.—La Compagnie Générale, Paris, exhibited a composite carriage with a combined wood and iron frame, suitable for short branch traffic. It contains accommodation for 8 first, 12 second, and 18 third class passengers, with a guard's compartment. It weighs 7 tons $7\frac{1}{2}$ cwt. It is constructed with a double roof, with special provision for ventilation.

BELGIUM.—La Compagnie Générale, Brussels, exhibited a carriage on six wheels, 30 feet long, $8\frac{1}{2}$ feet wide, in three compartments, the middle one being open at the sides, and railed as a lobby and promenade, from which the end compartments are entered by sliding doors. The under-frame has oak side-soles, strengthened with an iron plate, $\frac{1}{4}$ inch thick on the outside. The carriage weighs about 9 tons 17 cwt., its price is £500, and it is intended to carry 24 persons. This class of carriage is said to be well adapted for the picturesque country in which it is used, on the Namur and Liège Railway, where it has been in operation for twelve years.

PRUSSIA.—The Berlin Joint-Stock Company exhibit two carriages with iron under-frames, of which the sides are formed of double-headed girders, 10 inches deep, and 4 inches across the heads, affording good fixing ground for the body, and the scroll-irons to carry the springs. The centre springs are hung on swinging shackles, which leaves the centre wheels free to move laterally on the curves. The body of one carriage is about 30 feet long, divided into three compartments:—a coupé at one end, and two saloons, first and second class, with lavatories. The body of the other carriage is a third class, with guard's seat on the top at one end, inclosed with glass. There are two compartments, with six doors on each side.

The saloon arrangement of carriage has been better represented at the Exhibition than the

compartment system; and it is likely that Railway Companies will generally introduce first-class carriages with more of the character of the saloon than the universal partitioned carriages, originally introduced to represent a group of three ordinary stage-coaches. There can be no question of the superior convenience of the saloon over the compartment, for long journeys; in the latter, if formed with elbow-rests, a passenger can neither stand up nor lie down, except by improvising a couch, to the destruction of the cushions. Greater width across the carriage is desirable for the saloon than is usually given to the compartment, but carriages have been made nine feet wide, and are running on the Great Eastern and other lines without any difficulty in want of balance.

CHAPTER VII.

DETAILS OF RAILWAY CARRIAGES AND WAGGONS.

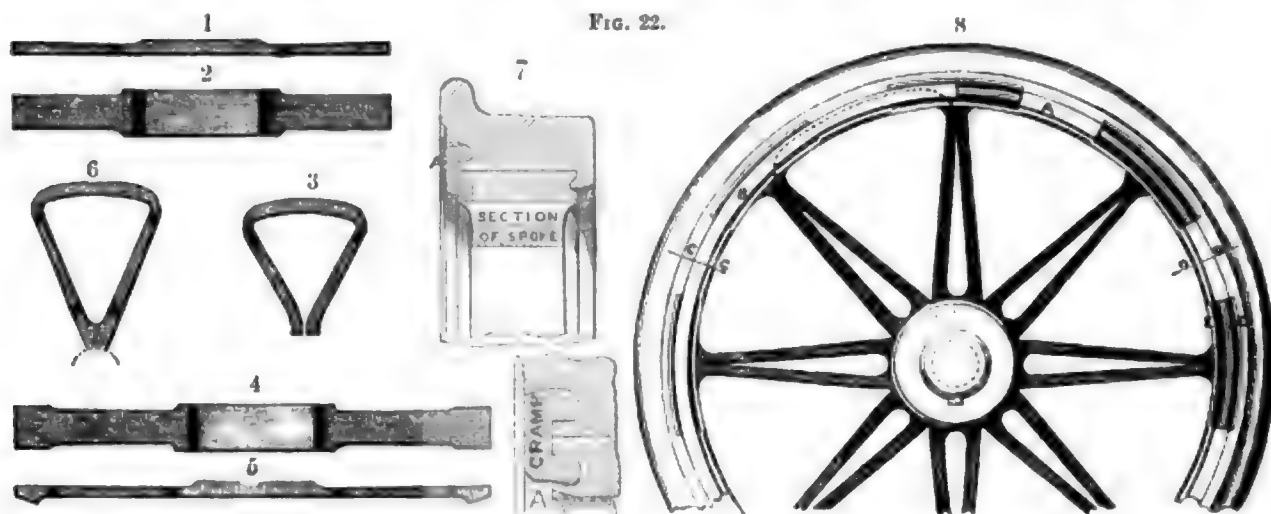
Railway Wheels.—Considerable progress has been made in perfecting the construction of railway wheels within the last few years. In the first place, the good old Yorkshire and Staffordshire tires are being gradually superseded by the superior tires of steel, first successfully introduced by Krupp of Essen, and now manufactured by several English makers. Again, the body of the wheel is now forged in one piece in one operation, instead of, as heretofore, in several operations,—thus removing antagonistic strains in the forging, and increasing their strength and trustworthiness. Further, the fixing of the tire on the wheels has been vastly improved; bolts, and nuts, and rivets, passing through the tire, are superseded by lateral fastenings, which do not weaken the tire, and materially add to the strength and security of the attachment. The best mode of fastening laterally is a point not yet decided by experience.

Mr. Owen, of Rotherham, exhibited wrought-iron wheels, axles, and tires. He has recently introduced M. Arbel's method, already described in connection with Cail's locomotive, of constructing wheels in one forging between two large dies sufficient to embrace the whole area of the wheel. He also exhibited solid weldless tires, made from a solid mass into a circular form. After being hammered and welded at one blow, they are rolled into a complete ring.

Messrs. Dixon and Clayton, of Bradford, exhibited their system of wheel, formed with spokes specially rolled, to give a broad bearing at the rim for the tire, as in the annexed figures, for the sake of greater stability and security than when rolled of the narrower width throughout; and, in conjunction with the fastening of the tire, to increase the durability of the latter,

inasmuch as it may be worn thinner before requiring to be replaced. The tire is fastened without bolts, by means of a V bearing on the inner edge, and cramps applied laterally at the outer edge, to embrace both the tire and the rim edgewise, the cramps acting as fasteners in themselves, and retaining the tire should it break. The cramps are usually applied in segments 4 inches long, and slightly dovetailed;

and being inserted in grooves of square section turned out of the edges of the tire and the wheel, the edges of the grooves are hammered over the dove-tail, and so fixed. The cramps may be slid laterally, and withdrawn, and the tire released when required. This system of fastening has been adopted on the North-Eastern, the Lancashire and Yorkshire, and other lines, with beneficial results (fig. 22).



ROLLED SPOKES AND CRAMP-FASTENINGS FOR RAILWAY WHEELS, by Messrs. Dixon & Clayton, Bradford. Figs. 1, 2, and 3, views of a Spoke-bar for a carriage-wheel, with a cast nave. Figs. 4, 5, and 6, Spoke-bars for a solid wrought-iron wheel. Fig. 7, A, is the cramp-fastening for tires. Fig. 8 shows the cramp-fastenings, at intervals, or continuous.

Mr. James Murphy, of Newport, exhibits a dovetail fastening for wheel-tires, the dovetail being formed on the inside of the tire, and let into the rim of the wheel. How the dovetail is to be got into the rebate does not clearly appear.

Messrs. G. and J. Brown, Rotherham, exhibit their "solid iron and steel-faced tires," which have been satisfactorily at work on some of the principal railways. The process of manufacture of the tires is described as follows:—The faggot for the bloom is composed of one bottom and one top coil of 1-inch square iron, with a series of layers of iron rolled from bloom into bar, 5 inches broad by $\frac{1}{4}$ inch thick, and then cut into sectional pieces, so as when placed side by side to form a circle of from 18 inches to 21 inches diameter. These sectional pieces are laid one upon the other, taking care that they break joint; and the piling is continued until the faggot attains the height of from 12 to 18 inches, according to the size of tire required. The faggot is then placed in an air-furnace, and heated until it has reached the welding point, when it is brought out and placed in a boss of suitable size, under a 7-ton steam-hammer having a 6-foot stroke, where it is reduced by continuous blows to the required thickness. The faggot is again placed in the furnace reverse side uppermost, and heated as before, when it is again put into the boss, with a wrought-iron pin 11 inches diameter placed in the centre to keep the hole in the faggot true. At this point the flange is formed, and the tire-bloom is finished

hammering. By this process of manufacturing tires, being solid, there cannot be a break at a weld, because there is no transverse scarf, and there is also the certainty of one uniform quality, quite equal to that of a homogeneous body. As the pile or faggot is laid up, the edges of the bar iron become the wearing surface of the tire, which not only increases its tensile strength, but makes it in consequence capable of withstanding a much greater amount of wear and tear.

The tire-bloom is then rolled to any diameter required, and is finished true internally and externally, and of equal thickness.

The faggots for the steel-faced tires are piled precisely in the same manner as for the iron tires, the only difference being that rolled bar-steel of the best Swedish quality is built up on the outside of the faggot, the inside being of iron, which undergoes the same process of welding and hammering as the iron faggots, until the bloom becomes perfectly sound.

Messrs. T. Spencer & Sons, Newcastle-on-Tyne, exhibited cast-steel tires in three stages of manufacture. 1st, the cast annular ingot, 30 inches diameter, 6 inches thick, with an 11-inch central opening; 2nd, the ingot reduced under the hammer to $4\frac{1}{2}$ inches thick; 3rd, the ingot rolled to 4 feet diameter, and 2 inches thick radially.

Mr. P. Wright, Dudley, exhibited a double-disc wheel; the discs are riveted to a flange on the inside of the tire placed between them.

Mr. W. B. Adams exhibited a method of

so applying the tire that the wheel rests on a continuous hoop-spring in a hollow in the tire. The tire is thus applied with a very light pressure, and prevented from coming off by a flat hoop sprung into a groove at the back of the wheel. The object of this application is to prevent the liability to burst or break, to which tires are usually subject, in consequence of the shrinkage and strain with which they are applied to wheels to insure tightness. The result of the performance is quite satisfactory. The wheels appear to be well suited for use on lines with quick curves. On one such line, the spring tires were applied under a locomotive-engine and ran 25,000 miles before being taken out to be turned up, when the flanges were found to be little worn. New tires applied in the ordinary manner, under the same engine, required to be turned up on account of the great wear of the

flanges, after having run 8,000 to 10,000 miles. It appears that, in practice, a slight sliding movement of the tire takes place upon the wheel, in going along curves, instead of the unavoidable sliding of fixed tires, and probably the greater duration of the flanges is to be ascribed to this cause, as well as to the vertical play of the tire, which permits it to follow the irregularities of the line of rail across the breadth, thus preventing blows. A set of these tires, of Staffordshire iron, applied to a heavy carriage, ran upwards of 106,000 miles without any alteration of form, and with very slight wear, and a pair of them were exhibited. The following table of the performance of four different qualities of tires shows results very recently obtained upon the St. Helen's Railway,—a line of remarkable difficulty as to curves, gradients, points, and crossings:—

COMPARATIVE WEAR OF FOUR CLASSES OF ENGINE-WHEEL TIRES
ON THE ST. HELENS RAILWAY.

No. of Engine.	Number of Wheels.	Number of coupled Wheels.	Diameter of coupled Wheels.	Weight of Engine.	Miles run.	Liability to Slipping.	Class of Tire.	REMARKS.
No.	Wheels.	Wheels.	Feet Ins.	Tons cwt.	Miles.			
23	6	4	4 6	19 15	40,843	Slips, even in dry weather.	Krupp's Steel	Needing to be turned up.
4	6	4	4 6	20 6	20,798	ditto	Best Yorkshire Iron	Ditto.
27	6	4	4 6	23 14	34,006	ditto	Swedish Iron	{ Ditto. Has been turned up once.
18	6	6	4 0	21 0	55,138	Scarcely ever slips.	Staffordshire iron, with spring tire.	Not needing turning up.

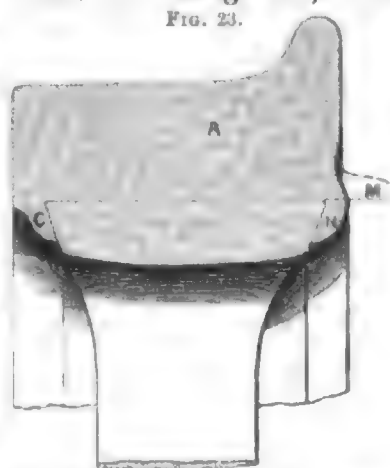
NOTE.—The traffic of this Railway is worked by these engines over 30 miles of line. The line is very heavy in gradients, curves, and points and crossings. The steepest gradient is 1 in 35; the two main gradients are 1 in 85 and 1 in 70. The quickest curve has a 300-foot radius; the ordinary curves have 500 feet radius. There are 12 miles of sidings within a distance of two miles from the principal station.

The best Yorkshire nearly duplicated the best Swedish in wear; Krupp's steel duplicates the best Yorkshire iron; and Staffordshire iron, on Mr. Adams's steel springs, may probably duplicate Krupp's steel.

This is an invention which, like the water-injector of Giffard, when first promulgated, was generally received with incredulity. It promises results of great importance; and, possibly, the benefit of the spring-bearing applied to the rails, as contemplated by Mr. Adams, may prove equally decided.

In Mr. Joseph Beattie's system of fastening tires on wheels, applied to the railway carriage exhibited by Messrs. Wright, the tire is lapped angularly against the inner edge of the wheel, and is secured at the outer side by segmental pieces at intervals, lapped under the iron and let with a dovetail into a groove in the inside of the tire, the sides of which are afterwards hammered over the dovetail. An approved variation is shown in fig. 23. In Mr. Burke's

plan, the tire is rolled with a thin ledge all round the flange-face, which is afterwards hammered over upon the edge of the rim.



TIRE-FASTENING, by Mr. J. Beattie:
A, tire; C, ledge; M, ledge rolled on tire; N, ledge hammered over the edge of the wheel, to secure the tire.

and support the nave than would be done with a flat disc.

Messrs. Naylor, Vickers, & Co., Sheffield, exhibited, in the Sheffield Court, various cast-steel disc-wheels. A pair of 7-foot driving-wheels have solid tires, and are cast with radial corrugations, the more widely to embrace

Messrs. Gargan & Co., Paris, exhibited forgings made of common iron, by means of hydraulic pressure. Messrs. Arbel & Co., Rive-de-Gier (Loire), exhibit some excellent solid forged wheels for locomotives and carriages. So also do the "Société Anonyme," Seraing (Liège).

Disc wheels are exhibited from Austria, Prussia, and Canada. Mr. A. Gauz, of Buda, exhibited two double-disc chilled-iron wheels, 3 feet 1 inch diameter; one new; the other, after having run 69,000 English miles and scarcely worn,—about $\frac{1}{8}$ inch,—just polished. The chilling action penetrated $\frac{1}{4}$ inch into the metal. The Bochura Company exhibited cast-steel wheels and tires, and showed a peculiar mode of fastening the tire. The tire is rolled with a T rib on the inside, embraced by a corresponding recess turned on the rim of the disc, with a closing ring applied laterally and fixed by screws. The body of the wheel is a single disc with circular corrugations to facilitate elastic action and increase the duration of the tire. Mr. Krupp, of Essen, and several others, exhibited cast-steel wheels and tires. Mr. Krupp exhibited samples of tires made for nearly all the principal English railways. A chilled cast-iron wheel from Canada was reported to have run on the Grand Trunk Railway 150,000 miles. It was double-disc, of $\frac{3}{4}$ inch metal, 32 inches diameter, with about $\frac{1}{8}$ inch wear on the tread, and the flange little worn. Messrs. Larue & Co., Three Rivers, also exhibited hollow cast-iron wheels.

There can be no doubt of the decided progress that has been made in the construction and manufacture of railway wheels during the last ten years. The solid wrought-iron wheels, forged at one operation; the solid iron and steel tires without welds; and the safety tire-fastenings, by the use of which bolts and nuts are dispensed with, and the tire, if it breaks, is prevented flying off the wheel;—these appear to be the chief elements of progress on which railway engineers and the railway public may congratulate each other. The performance and durability of the hollow cast-iron wheels with chilled tires, from the Continent and from Canada, are something marvellous; and probably something remains to be done in England with this sort of wheel. The wrought-iron or steel disc-wheel is not likely to displace the spoke-wheel; the latter is sufficiently strong; it is lighter than, and is not so rigid as, the former. The result is, that tires wear longer on the spoke-wheel. The only advantage that has been urged in favour of the disc,—that it does not fan the dust on the road,—is not material, as the general agitation of the air caused by the passage of a high-speed train has the most to do with the raising of the dust. Probably, the hollow cast-iron disc-wheel embodies the best design of a spokeless wheel.

Springs.—Mr. A. Allan, Perth, exhibited a new laminated spring, intended for a varying

load. The largest plate is below, and curves upwards at the ends, the spring resting on the axle-box by the middle or butt. As the spring deflects under a load, the second and the shorter plates successively take a bearing against stops on the frame, and thus become elastic props. The object in this design is to make a lighter and easier spring for varying loads; but it is doubtful whether the slight saving in this respect is not more than counterbalanced by the stiffness of the plates and the want of action and mutual support amongst them.

Mr. W. B. Adams's "abutment springs" are open to the same objection. They are ingenious, as all Mr. Adams's inventions are. They do not require scrolls, shackles, or slides. The springs are in two halves, composed of two or more curved plates. The upper ends abut in a tension bar or in a shoe on the frame, and the lower ends in or below the axle-box, in loops of a saddle passing round it. As the load descends, the springs bear against the tension-bar, and thus shortens its elastic length and carries a greater load. They are said to be elastic and lively in action, but it is obvious that, the heavier the load, the stiffer and less elastic they become,—an objection which does not apply to the ordinary spring.

Messrs. C. Cammell & Co., Sheffield, exhibited a laminated spring, in which the ordinary slots and studs are dispensed with, and the plates are kept parallel by means of ribs rolled on the edges of every alternate plate, and lapping over the intermediate plates. This plan is of doubtful efficiency. The ribs would be liable to crack under heavy and fluctuating loads.

Messrs. Thomas Spencer & Sons exhibited the volute and other springs, for the manufacture of

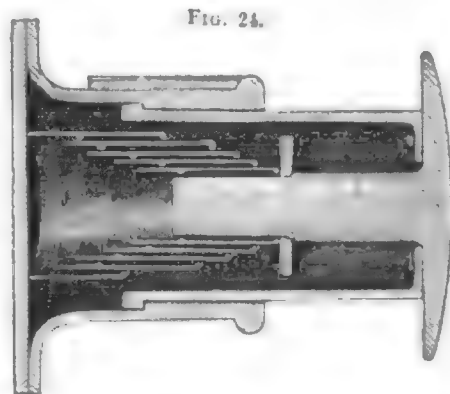


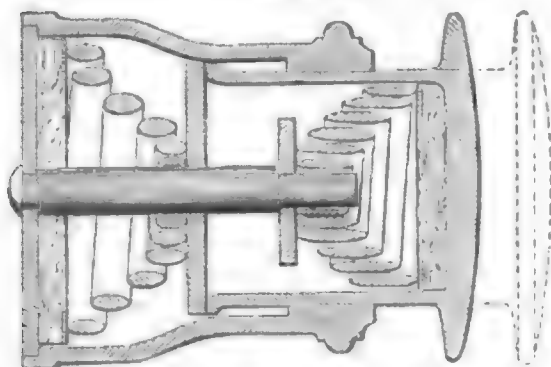
FIG. 24.
VOLUTE SPRING BUFFER, by Mr. H. L. Corlett, formed of ribbed steel, to work without friction.

which they are well known: in particular, and in conjunction with Mr. H. L. Corlett, Dublin, a waggon-buffer, in which the casing, plunger, and head, are all of wrought iron, to combine strength with lightness. The flange has not the usual central bolt, but is retained in position in the casing by a fillet round the inner extremity. The spring is an improved volute, having two very small ribs rolled on one side, which

reduce the sliding friction by keeping apart the coils of the spring (fig. 24).

Mr. A. Allan exhibited a compound buffer having two springs with independent action, to

FIG. 25.



COMPOUND BUFFER, by Mr. A. Allan, with two springs.

give double the resisting power in less than double the compass (fig. 25).

Messrs. Bradley & Co., Sheffield, exhibited a buffing and drawing spring, in which two helical springs are placed in diagonal shackle-frames, transversely to the line of traction, one at each end of the carriage frame. The direct pull is received by the shackles, and the office of the spring is to resist their collapsing. By the same mode of action, with the aid of a cross-bar to compass the buffer-rod ends, the spring is opposed to the buffing strain. This spring is made with only half the weight of steel necessary for a laminated spring, and it may answer satisfactorily for gradual and steady strains. But it will not work so well in resisting shocks, whether of traction or buffing, as the play or "action" in the direction of traction is limited by the mode of application.

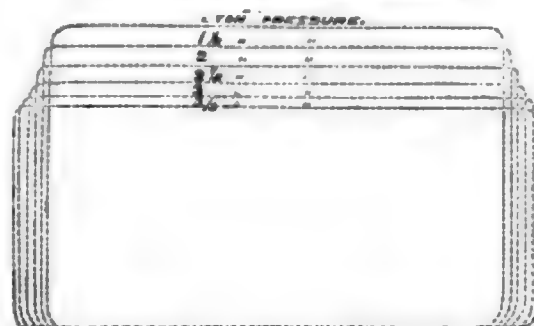
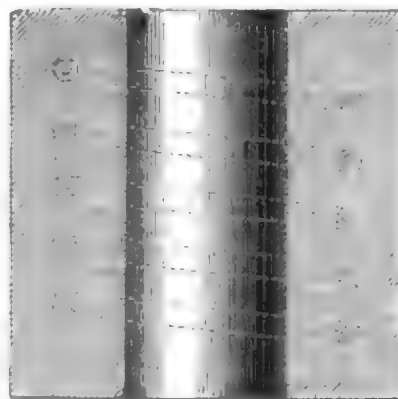
Messrs. S. Moulton & Co., Bradford, Wilts, exhibited their "embedded steel and india-rubber springs," consisting of a hollow cylindrical mass of india-rubber, with a helical coil of steel-wire embedded in its substance. A spring of this sort, 5 inches diameter, 5 inches long, with a 2-inch hole, and having six coils of $\frac{1}{4}$ -inch steel wire, was loaded with an increasing weight, with the following amounts of compression,—

Load in Tons.	Compression in Inches.	Reduced Height in Inches.
0	0	5
1	1.25	3.75
1½	1.55	3.45
2	1.78	3.22
2½	2.00	3.00
3	2.16	2.84
4	2.30	2.70

Showing a total compression of about 2½ inches under 4 tons of load, of which three-fourths took place with half the load. The same size of india-rubber spring, without the steel wire, was compressed 3 inches by 2 tons load, two-thirds of which took place under half the load. The same objection appears in this spring as in some others,—that the "action" is very limited and

very unequal, reducing the spring to nearly a rigid mass under the greatest load, which is the chief objection to the use of india-rubber; but

FIG. 26.



EMBEDDED STEEL and INDIA-RUBBER SPRING, by Messrs. S. Moulton & Co.

the steel wire adds to the resisting power of the india-rubber (fig. 26).

Couplings.—Mr. C. Little, Bradford, exhibited a safety coupling for waggons, the object of which is to enable the men to couple and uncouple waggons without having to pass between the buffers, by means of a handle on each side of the waggon. The coupling link is connected to the draw-bar by two straight links with pins, and is balanced on its connecting pin with counterweights. This pin or pivot is fixed in the ends of the coupling link, and is made with a "tripping-catch" forged on it in the middle, which is acted on by a lever worked by the handle at the side of the waggon, whereby the coupling link is enabled to pass up clear of the opposite drawhook in lifting, and is then extended forwards to reach over the hook for coupling the waggons; whilst, in uncoupling, it is first disengaged from the hook and lifted up, and then swings free into a vertical position, so as to drop clear of the hook in lowering. The coupling has been tried with good results on the Midland Railway. It appears to be heavier and more costly than ordinary couplings.

Carriage Brakes.—"Widely different as may be the opinions of railway men," says Major Yolland, in the Report of the Jury on Class 5, "on the practicability of applying a much larger proportion of brake-power to passenger trains than they are now usually supplied with, there

are few that will dispute the assertion that if it can be practically done, a much greater proportion of brake-power should be allotted to trains that travel over portions of their route at rates exceeding fifty and sixty, and probably in some instances approaching to seventy miles an hour, than to those which do not exceed half that rate. The divergence of opinion usually arises when the means of carrying out such a proposition are discussed. Locomotive superintendents generally contend, and with much reason, that as the driver of a train usually becomes aware of an obstruction on the line on which he is travelling, in front of his train, before any other person, he is the proper person to be supplied with the retarding force necessary to arrest the progress of his train before the obstruction is reached; but generally they fail to carry out their own theory to the extent which the vehicles exclusively under the control of the driver would readily admit of. Thus, no brakes are usually applied to any but tank-engines,—the brakes at the control of the driver are limited to those put by his fireman on the tender;—and experience has proved that there are numerous instances on record where it would have been highly expedient, and have led to the saving of human lives, that the guard of a train should have had a large retarding force at his command at the tail of the train."

Major Yolland has probably had a greater variety of experience of the action of brakes than most engineers, and is a competent authority; and there can be no question as to the soundness and importance of his observations. Steam-brakes have been tried in various modes on locomotive engines with tenders; but none of them appear to have established themselves. The truth is, enginemen will not use steam-brakes at ordinary work, and such brakes fall into disuse and become a nuisance. They, in fact, improvise a steam-brake, in cases of emergency, by reversing the engine and turning on the steam against the pistons, which is certainly the most efficient form of engine-brake, and leaves practically nothing more to be desired, except that provision should be made that the pistons and cylinders should not be overstrained in the process by excessive compression of steam. Probably the best way to apply steam-power to brakes, would be to use it entirely in place of the hand-lever and screw-brake on the tender, extending its connections to the train.

Mr. Newall, of Bury, and Mr. Fay, of Manchester, exhibited models of the brakes well known by their names. Mr. Newall is understood to be the first inventor of continuous brakes on railway trains in this country. They were first extensively used on the East Lancashire Railway in 1853,—a line of very steep inclines and sharp curves, and when constructed they consisted of a longitudinal revolving shaft, placed under the framing of each carriage, those under adjacent carriages being connected together

by short coupling-rods, with slides and universal joints, provision being made for any difference in the heights of the carriages, and for a shortening of the train when the buffers are driven home. On one of the longitudinal shafts a bevelled wheel is fixed, into which another works, which is fixed on an upright shaft. This upright shaft passes into a guard's van, where motion is communicated to it by wheels and pinions set in motion by an ordinary wheel or handle. On the spindle of this handle there is a ratchet-wheel, with a light catch for retaining it in a state of rest; the catch is weighted at the opposite end, so that it may readily fall or be pulled out, and be kept out of action, except when put on by hand. At the other end of the carriage, a small pinion is fixed on the longitudinal shaft, which works into an upright double rack, capable of being raised or lowered as the longitudinal shaft and pinions are turned in one direction or the other. The bottom of this double rack is attached to the end of a long lever fixed on to the transverse rocking or brake-shaft, usually placed midway between the leading and trailing wheels of a carriage, so that the raising or lowering of this rack by the turning of the longitudinal shaft turns the rocking shaft, and forces the brake-blocks against the peripheries of the wheels. Formerly, weights were attached to the end of the long lever, so that when the catch was taken off, the weights caused the end of the long lever to descend, and then forced the brake-blocks against the peripheries of the wheels; but strong spiral springs inclosed in a cylinder have been substituted for the weights, and these springs are in some cases made to act upon the longitudinal shafts, or directly upon the rocking-shafts, thus causing the brake-blocks to be forced simultaneously against the wheels when the catch is liberated. These spiral springs constitute the self-acting part of the brakes. The principal portion of the work of the guard of a train fitted with a set of these continuous brakes, consists in turning the longitudinal shafts, so as to withdraw the brake-blocks from the wheels. The labour of putting them on is greatly lessened by the assistance of the spiral springs. This brake is a step in the right direction, but it is not a perfect continuous brake, as there are no self-adjusting means by which the pressure on all the wheels of the brake-blocks might be equalized. This brake is now ordered to be adopted throughout the Yorkshire and Lancashire railways, including the East Lancashire section, formerly a separate railway, on which, as already stated, it was first brought into operation; it is in use partially on many other railways, and a set has now been for some time on trial on the London and North-Western Irish express mail train between London and Holyhead, and is favourably reported on.

Mr. Fay's brake, also continuous, being fitted on to several carriages in a train, may be like-

wise worked by one guard from a brake-van placed at the ends or in the centre of a train. It acts by means of a longitudinal shaft attached to the under side of the frame of the carriage or brake-van, the shafts under the adjacent carriages being connected together by notched couplings. The guard, by the use of ordinary machinery, turns these longitudinal shafts, on which endless screws are fixed, opposite, and working into rackwork attached to the rocking or brake-shafts under each carriage; and thus when the longitudinal shafts are turned, the brake-blocks are forced against the periphery of the wheels of the several vehicles so connected together, usually not more than three or four. This brake is simple in its construction and powerful in its operation when in thorough adjustment. It has the same defect as Mr. Newall's, as there are no self-adjusting means by which the pressure of all the brake-blocks on the wheels can be equalized. It is stated to have long been advantageously used in connection with the working of the passenger traffic on the Oldham incline of 1 in 26, on the Lancashire and Yorkshire Railway; and on short lines, where the same carriages mostly run to and fro, forming part of the same train, and which are not much interchanged; and it has now been for some time on trial on the very fast Irish express mail-trains on the London and North-Western Railway, between London and Holyhead; and thus far the reports of its working are favourable.

Guérin's brake, which is well known, was exhibited in the French department. It is in use on several French railways,—as the Eastern, the Orleans, and the Lyons. It has not found favour in England.

The Lyons Railway Company exhibited a self-acting brake for very steep inclines, intended to come into operation should the train break loose. A flanged pulley is lowered to the rails, and is screwed up against and wedges the flanges between them. It is not very obvious how this is to work, and if it could work it would be highly dangerous.

Another French brake was exhibited, in which the lower frame of the carriage may be rested on the rails, forming a sledge-brake with its whole weight. By means of levers it can be lowered and raised at pleasure. With suitable precautions the principle of this brake may be properly worked, but it wants better mechanical arrangements.

M. Achard exhibited an electric brake, which has been tried in France.

CHAPTER VIII.

PERMANENT WAY.

There was nothing remarkably novel in permanent way. The double-headed rail continues

to be the leading pattern of rail, with the ordinary chairs and the ordinary sleepers. The Permanent Way Company exhibited a variety of appliances for the improvement of details,—chiefly with regard to the fish-joint for rails,—which merit a brief notice. They in the first place exhibited the mode of making the joints of rails before the advent of Adams and Richardson's invention for suspended fish-joints,—showing the rails in a bad state, out of level, and the chairs off the plumb. The advantages of the suspended fish-joint are now unquestioned, in giving a firmer rail, and an unbroken tread for the wheel, and admitting of higher speeds, with greater safety and comfort to travellers than formerly,—resulting in considerable economy of maintenance, amounting, it is said, to 50 per cent. by its use on about 12,000 miles of rail.

The late Mr. C. H. Wild's improvement is exhibited; the fish-plates are made with grooves instead of plain sides, making them lighter and stiffer, and at the same time securing the heads of the bolts, or the nuts, from turning round when being screwed up, or getting loose by usage, or other contingencies. In Mr. William Pole's improvement one of the fish-plates is tapped, and the bolts are screwed into it without nuts. This is useful with flat-based or shallow rails, where wheel-flanges might strike the nuts or bolt-heads. In Messrs. Barlow and Woodhouse's system, the fish-plates rest at their ends in cast-iron chairs in halves, to obtain additional strength, and obtain the advantages of the joint,—the end-bolts being passed through and uniting the half-chairs. The same fixing is applied to chairs with single "jaws." Messrs. R. Richardson and J. E. Billups show a mode of fastening the fish-plates, by tapping them both with right- and left-hand screws, and screwing the bolts into them to draw the plates together without bolt-heads or nuts, which reduces the number of parts. The bolts, it is said, never get loose. Mr. A. Doull employs two half-chairs of rolled iron, bolted together through the rail,—superseding cast-iron chairs, wood keys, and fish-plates, and being lighter. In Mr. P. Ashcroft's chair, the rail is supported in the chair by means of two wooden cushions, one on each side, with a wedge-like pressure; they save the rail from indentation on the seat of the chair. Hollow iron spikes, invented by the late Mr. May, and by Mr. Prince, were exhibited, by which means a firmer hold is supposed to be obtained on the sleeper than by solid iron spikes or wooden trenails. They are made quill-pointed, to penetrate the sleeper without boring a hole or splitting the timber. Examples of the application of Dr. Boucherie's process for preserving timber were exhibited—portions of a railway sleeper and a telegraph pole. This process consists in injecting, under pressure, an antiseptic fluid into the pores of the timber at one end, forcing out the sap at the other, and thus completely occupying the substance of the wood. For this

purpose, the worst kinds of timber are said to be best adapted. A very weak solution of sulphate of copper best answers the purpose as a fluid for injection.

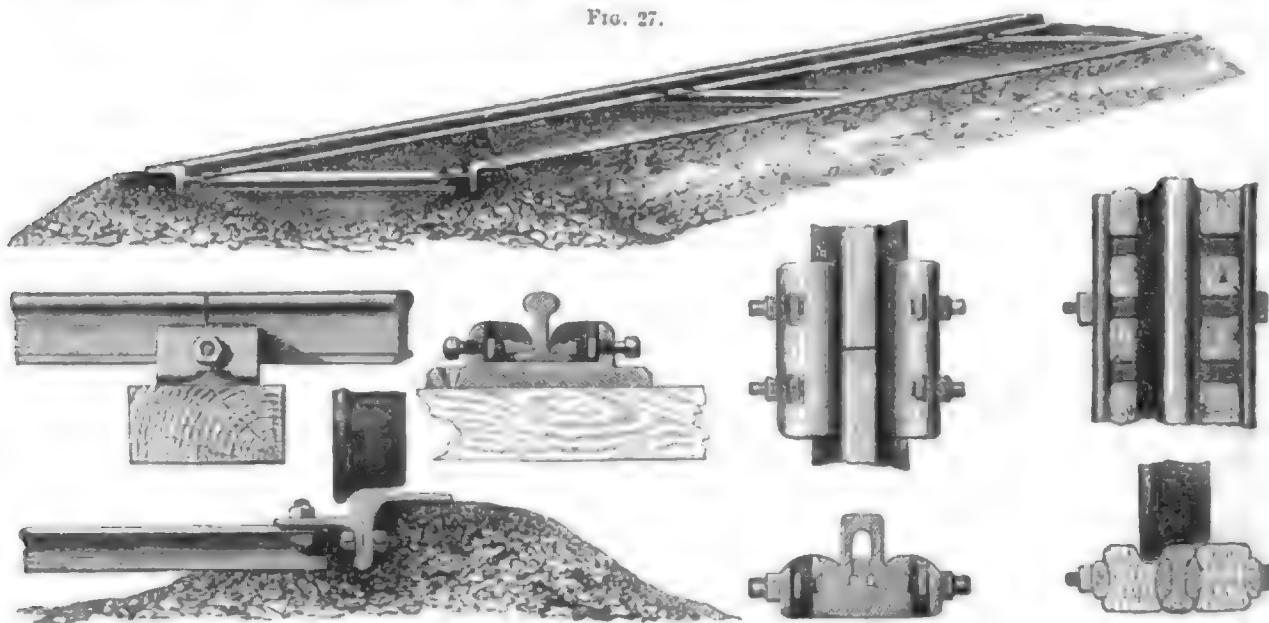
Mr. F. Wise, London, exhibited Ramié's railway-chair, in which the double-headed rail is suspended in the chair by means of a pair of "tumble-jaws," or self-tightening three-throw brackets,—one throw of which rests upon the jaws of the chair; another throw laps under and supports the rail, and the third throw is pressed against the web of the rail, in a self-acting manner, by the weight of the rail acting through the pair of triangular levers. The heavier the load passing over the chair, the more firmly do the "tumble-jaws" bite and secure the rail. This

chair is said to have stood the test of several years' trial.

Messrs. Ordish & Le Feuvre, Westminster, exhibited an elastic railway chair and sleeper, in which the rail is suspended between two cast-iron keys or cushions, similarly to Mr. Ashcroft's system with wooden cushions; and for the same purpose, to prevent the rail from indenting in contact with the bed of the chair. To secure the keys, they are serrated, having ratchet-shaped teeth, to fit into corresponding teeth in the jaws of the chair, which are sprung open to admit them.

Mr. H. L. Corlett, Dublin, exhibited a continuous, surface-supported rail, in two parts, bolted together, and breaking joint; thus complete,

FIG. 27.



IRON PERMANENT WAY, by Mr. H. L. Corlett.

without either sleepers, chairs, or fish-plates,—and being easily accessible from the surface of the ballast for repairs. This is a modification of Mr. W. B. Adams's girder rail, which was not exhibited. Mr. Corlett's rails were laid down in the Western Annex, to carry the locomotive engines exhibited. Cast-iron joint chairs for bridge and foot rails were exhibited, with wrought-iron wedge keys placed above or below the flanges; they are set up and fastened by bolts and nuts. There were also double-headed rails, with cellular cast-iron brackets bolted on the sides, the cells being filled with timber, concrete, or other materials; applicable for street railways (fig. 27).

Mr. G. E. Dering exhibited a "spring-clip fish-joint" of tempered steel, and spring keys and trenails of the same material. Also, examples of rails united at the ends by hard-soldering, which are said to have been exposed without injury to four years' traffic on the Great Northern Railway.

Mr. J. Morris, London, exhibited an iron wedge, to replace the ordinary wooden wedge for railway chairs.

Mr. T. Wright, London, exhibited his "patent bed-plate iron solid transverse sleeper permanent ways," with wooden cushions and double-headed rails,—a title which explains the nature and advantages of the system. Also, his "safety railway," with a "safety kerb" cast on the sleepers, parallel to, above the level of, and outside the rail, at each side of the line. It is designed to prevent engines or carriages leaving the line should they break down, and to offer a friction-surface for the application of sledge-brakes. He exhibits, moreover, his "patent bed-plate iron-girder solid sleepers and rails," for street tramways; consisting of cast-iron rails, moulded into six and twenty different shapes,—one piece with eight wearing surfaces,—let flush into the street.

Mr. T. Truss, London, exhibited a "cushioned railway chair," having a layer of elastic material on the chair, as a bed for the rail.

Messrs. Ransomes & Sims, Ipswich, exhibited a series of their well-known and well-tried compressed keys and trenails for railway chairs, &c. They are made of the best wood, which is cut out much larger than the finished size, care-

fully desiccated, and then compressed by machinery. When driven into their places, they return, under the influence of rain and moisture towards their original size, and completely fill the receptacle made for them. These fastenings are, in some instances, injected with the vapour of creosote, which increases their durability.

Mr. W. B. Adams, London, exhibited bracket-joints, in which a wide-footed piece of angle iron is bolted to the double-headed rail on each side, forming a base to rest on the sleeper; the advantage being that wood keys are dispensed with, that they are little more than half the weight of ordinary chairs, and that the rails, bearing on sleepers, do not get indented on the under side.

Mr. J. Ramsbottom, of Crewe, exhibited wrought-iron chairs, formed by cutting off lengths from a continuous rolled bar. They have a pair of wedge-form jaws, into which wrought-iron wedges are driven, one on each side of the rail, by which the rail is suspended with the lower table clear of the chair, similarly to Mr. Ashcroft's chair with wooden wedges.

The Anderston Foundry Company, Glasgow, exhibited an arrangement of metallic wedge keys. There is no doubt that iron keys, perfectly applied, are better than wooden keys. The chief difficulty lies in keeping them tight, and this can only be done by making the wedge very acute, and then there is a great risk of breaking the chair. But there is also a difficulty in securing a fit, between the surfaces of wedge, chair, and rail, sufficient to prevent the first getting loose. This is accomplished, in the example under notice, by driving the key between two nearly concentric curved surfaces,—one formed by the chair face, and the other by a casting fitting the rail channel. By this arrangement, any inaccuracy in the wedge is compensated for by moving the casting more or less along the channel of the rail.

Messrs. Köstlin & Battig, Vienna, exhibited a rail with a continuous wrought-iron bearing, formed of two spreading angle-irons bolted to the sides of the rail, which is made with a single head, the angle-irons resting on the ballast. This is a variation of the old Barlow rail. As the angle-irons incline a little downwards on each side, forming a recess under the rail, they must suck up water and retain it, and there must be a liability to rock on the ballast.

M. Mazilier, Paris, exhibited a double-headed rail, with angle-brackets bolted to the sides of the rail, the horizontal wings being just under the upper head, to rest on the ballast, and supersede sleepers and chairs. This is but a repetition of one of Mr. W. B. Adams's forms of permanent way.

Mr. Seaton, London, exhibited a system of permanent way, in which a "saddle-rail," resembling in outline the Barlow rail, is bolted to a half-baulk of timber, cut diagonally, with the apex upwards. This gives longitudinal and horizontal stiffness. But the rail, apart from the timber, has not much stiffness, and it is therefore important that the timber should not be



SADDLE-RAIL, by Mr. Seaton.

liable to warp or twist. The base is broader, with a given quantity of timber, than in the rectangular sleeper applied under the bridge-rail; but the difficulty of disturbing the ground, and getting at it to pack, is the same. The rails are screwed to the sleepers, but it is likely that bolts would be better than screws, as was experienced on the Great Western Railway. There is, nevertheless, a good principle in Mr. Seaton's rail, and it deserves to be thoroughly worked out (fig. 28).

The Butterley Iron Company exhibited a double-headed rail, $5\frac{1}{2}$ inches deep, weighing 65 lbs. per yard, and rolled in one piece to a length of 117 feet. With this they exhibited a wrought-iron double-headed girder, 16 inches deep, $6\frac{1}{2}$ inches across the head, weighing 183 lb. per yard, and 60 feet long, in one piece.

The Governor and Company of Copper Miners in England, Cwm Avon, exhibited a bridge-rail, 90 feet long, weighing 58 lb. per yard; and, to contrast with it, a lilliputian flanch rail, weighing only $3\frac{3}{4}$ lb. per yard, 63 feet in length.

In the examples of permanent way exhibited, there is little requiring critical notice. The suspended double-headed rail is likely to be universally adopted in some one or more of the forms in which it has been exemplified; and of these, Mr. Adams's, Mr. Ashcroft's, and Mr. Ramsbottom's, are the most promising. The fish-joint, with the various little improvements elaborated upon it, has been thoroughly recognised, and has taken its place in the railway system; it is the greatest improvement which has been made in permanent way during the last ten or twelve years.

CHAPTER IX.

FIXED PLANT.

Railway Switches and Crossings. — The chief concern in dealing with switches and crossings is to insure smooth action, so that trains

may pass through them at high speeds without shock ; and, next, to obtain durability, particularly in crossings, for in these the gaps which are required to be formed in the rails, for the crossing of the wheel-flanges, are unavoidably a source of wear, and, when worn, a source of danger.

Mr. P. M. Parsons exhibited the old and well-known "Wild & Parsons' switch," which was the first to take the place of the ordinary notched switches and rails. The fixed rails are retained entire and uncut, and the switches are formed out of rails specially rolled, with a broad base and reduced height, having the points housed under the fixed rails when closed, so as to afford a steady and continuous passage for wheels. The tables of the chairs on which the tongues slide, being elevated, are easily oiled and cleaned, and they keep the tongues free for action, clear of ballast or other obstruction.

Messrs. W. Baines & Co., Birmingham, exhibited switches and crossings, of which the former are based on the principle of Wild's housed switch, but are more elaborated. The switch is called a self-clearing switch, as the tables on which the tongues slide are diagonally placed, and a little elevated, that the tongues may clear away dirt or other deposit in sliding. The tongue is also made very deep and strong, and is housed, for greater stability, under the lower as well as the upper table of the fixed rail. The crossing is formed of rails rolled specially, faced with steel welded on the upper and lower surfaces, and reversible ; they are united to the contiguous rails by fish-plates. Both the switches and the crossing give evidence of careful elaboration in detail. A variety of crossing is also shown (Baines & Woodhouse's), in which the point-bar, all of wrought iron, is suspended in the chair by its upper table, thus saving the lower table from wear in the chair ; and the point may be reversed.

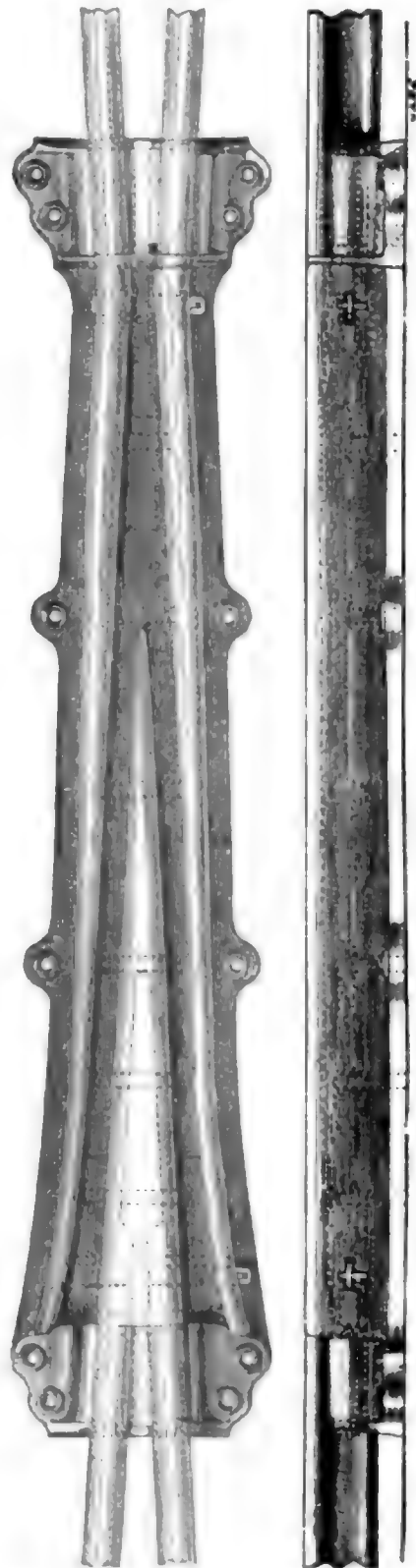
Mr. Robert Richardson, Westminster, exhibited railway switches on the principle of Wild's ; and rail-fastenings, like those which have already been noticed amongst the objects exhibited by the Permanent Way Company.

The Isca Foundry Company exhibited a variety of switches and crossings and other railway furnishings.

Mr. G. A. Biddell, Ipswich, exhibited Ransomes & Biddell's "solid cast-iron chilled railway crossing." As the name indicates, these crossings are in one piece ; and the principle is sound, for the violence and variety of the strains to which a crossing is subject, demand the most solid union of parts, as well as the utmost degree of durability. These qualities are united in the chilled crossing, as toughness is insured in the body of the casting, and durability in the chilled surface, which surpasses any combination of iron and steel for wearing. The casting weighs about half a ton for ordinary angles—say 1 in 9. Since the introduction of the chilled crossing, in 1856,

it has been extensively used on railways of heavy traffic, without any accident. They have been proved to last seven or eight times as long

FIG. 29.



CAST-IRON RAILWAY CROSSING, by Mr. G. A. Biddell.

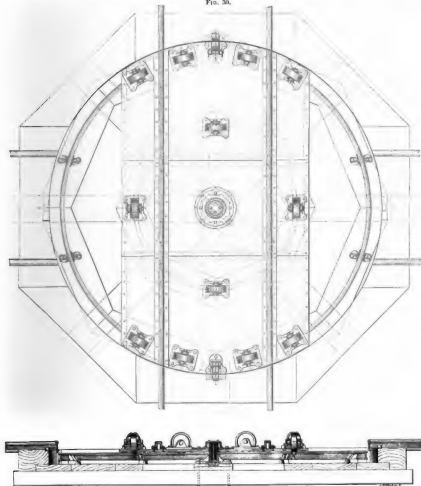
as common crossings, and are reported to have outlasted even the reversible cast-steel crossings (fig. 29).

The "Wild & Parsons' switch" is not likely to be superseded by any other yet produced ; and it is probable that the chilled crossing will supersede all other known crossings.

Railway Turntables and Traversers.—Messrs. Thomas Dunn & Co., Manchester, exhibited two wrought-iron surface turntables, 15 feet diameter, supported on a cast-iron centre, and by rollers on two rings formed of ordinary rails, keyed into ordinary chairs fixed on a timber foundation. The table is of plate iron, with one line of bridge rails riveted upon it.

The rollers are 8 inches diameter, and revolve with the table. The total depth, from the level of the rails to the upper surface of the wood foundation, is about 11 or 12 inches. The iron work of the table weighs 3 tons. Both tables were laid down in working order in the Western Annex, to connect the lines of rails laid down for moving the goods on trucks: they were

FIG. 30.



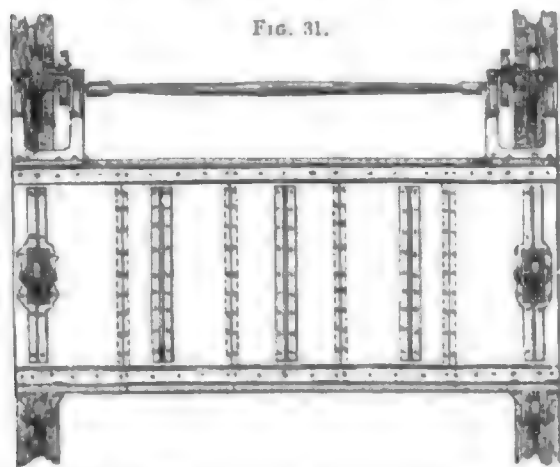
WROUGHT-IRON SURFACE TURNTABLE, by Messrs. T. Dunn & Co.

thoroughly well made, and worked most successfully under the severest usage, subject to shocks of every kind, owing to the nature of the work and the steep incline from which the trucks were delivered upon the turntables.

Messrs. Dunn & Co. also exhibited the curb of of a "double strong-ringed railway turntable," to carry 50 tons; the turntable is suited to carry a revolving mortar, and to bear the discharge. It will bear with ease the passage

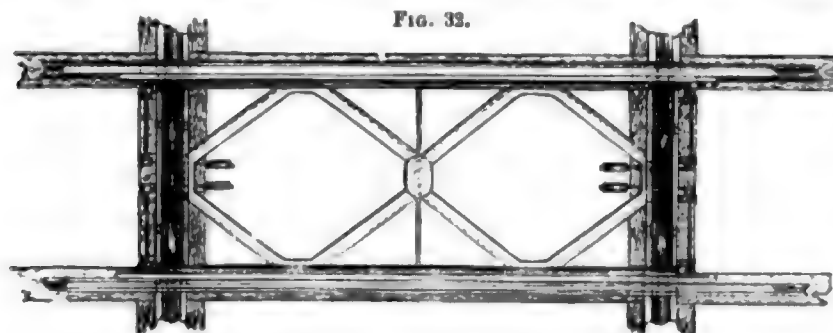
of locomotives at high speeds, as the table is, when stationary, lowered upon a series of solid rings; and is raised, for working, upon a central pivot, by means of suitable gearing. A cast-iron surface turntable was also exhibited, for warehouses and railway sidings, similar to the wrought-iron tables above described (fig. 30).

A traverser for locomotive engines and heavy goods, and one for carriages, were exhibited. The carriage-traverser is used for moving carriages and waggons from one line of rails to another without the use of turntables, and without damaging or weakening the main line. A line of rails is laid down across the lines for carriages, on which the traverser runs, and is shifted. The traverser has a shelf on each side, with flat rails, upon which the carriage is run up by means of self-acting inclines or points attached to the ends of the traverser; the carriage is then shifted sideways across the rails, upon the traverser, to any other line of



ENGINE-TRAVERSER, by Messrs. Dunn & Co.

rails. Many useful adaptations of the traverser may be made. The engine-traverser was laid down in working order in the Western Annex, and was used to traverse the locomotive engines to their places for exhibition, which was done quite successfully. The traverser is 20 feet long, and is fitted with gearing to be worked by hand,



CARRIAGE-TRAVERSER, by Messrs. Dunn & Co.

with a small number of men; the main line was fitted with turnover rails, which formed, in fact, a part of the main line, and were turned completely over on hinges, out of the way of the traverser, when it was at work, or when it stood

in the main line, supplying for the time the place of turnover rails. By this means the rails on the traverser can be placed level with those of the main line, and thus engines, tenders, or heavy-loaded waggons, may be placed upon it without the difficulty of ascending an incline as in the carriage-traverser. The traversers were most creditably designed, and were substantially made and put together. The weight of the traverser is about $7\frac{1}{2}$ tons (figs. 31, 32).

Messrs. Lloyds, Foster, & Co., Wednesbury, exhibited a "self-centering turntable," patented by Mr. W. H. Ward, Utica, New York, and also exhibited by him in the American department. The table is 13 feet diameter. The top is framed together with plates, angle-iron and T iron, with a wooden deck and one line of bridge rails. It has not the usual centre-pin, but instead of this is carried on a number of hollow cast-iron globes, 12 inches diameter, which revolve freely in a circle 7 feet diameter between two cast-iron rings hollowed out on their running tracks to embrace the globes sufficiently to keep them from leaving the circle. The foundation is of wood, and the curb is of $\frac{1}{4}$ -inch plate iron. The whole design is light, and is only adapted for quiet operations; yet the table weighs $5\frac{1}{2}$ tons. It turns very freely; at all events it did so in the Eastern Annex, where it was kept moving, with a load of wheels and axles.

Messrs. Baines & Co. exhibited a "united wrought-iron girder turntable," of which the top is built of iron girders, consisting of three double-headed plates or beams, put together side by side with tongues and grooves, and bolted together to form the girders. This mode of construction no doubt combines strength and stiffness, but there are too many pieces (fig. 33, page 41).

The "Société Anonyme," Maubeuge, Nord, exhibited a carriage turntable, consisting of cast-iron framing, with a wooden deck.

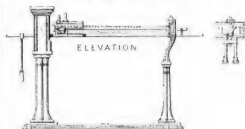
Weighing Machines.—"A correct balance is a just arbiter between buyer and seller." So say Messrs. Henry Pooley & Son, of Liverpool, who exhibited a variety of weighing machines. The principal machine exhibited by them was one called "Locomotive-engine weighing and adjusting tables," showing, by one operation, the total weight of the engine, and also the weight on the rail at each wheel (Plate V.). They were laid down in the Western Annex, forming part of the mixed gauge of rails laid to carry the engines. They may

be treated as one machine, and they consist of six independent weighing rails, with six steelyards or indicators, one to each rail, which can indicate from $\frac{1}{4}$ lb. up to 7 tons each, therefore capable of weighing an engine of

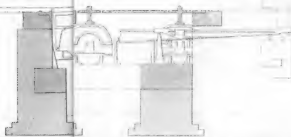
MOTIVE ENGINES



OF STEELYARD, SHOWING THE APPLICATION OF THE FINGER SHAFT
SCALE $\frac{1}{2}$ INCH TO ONE FOOT



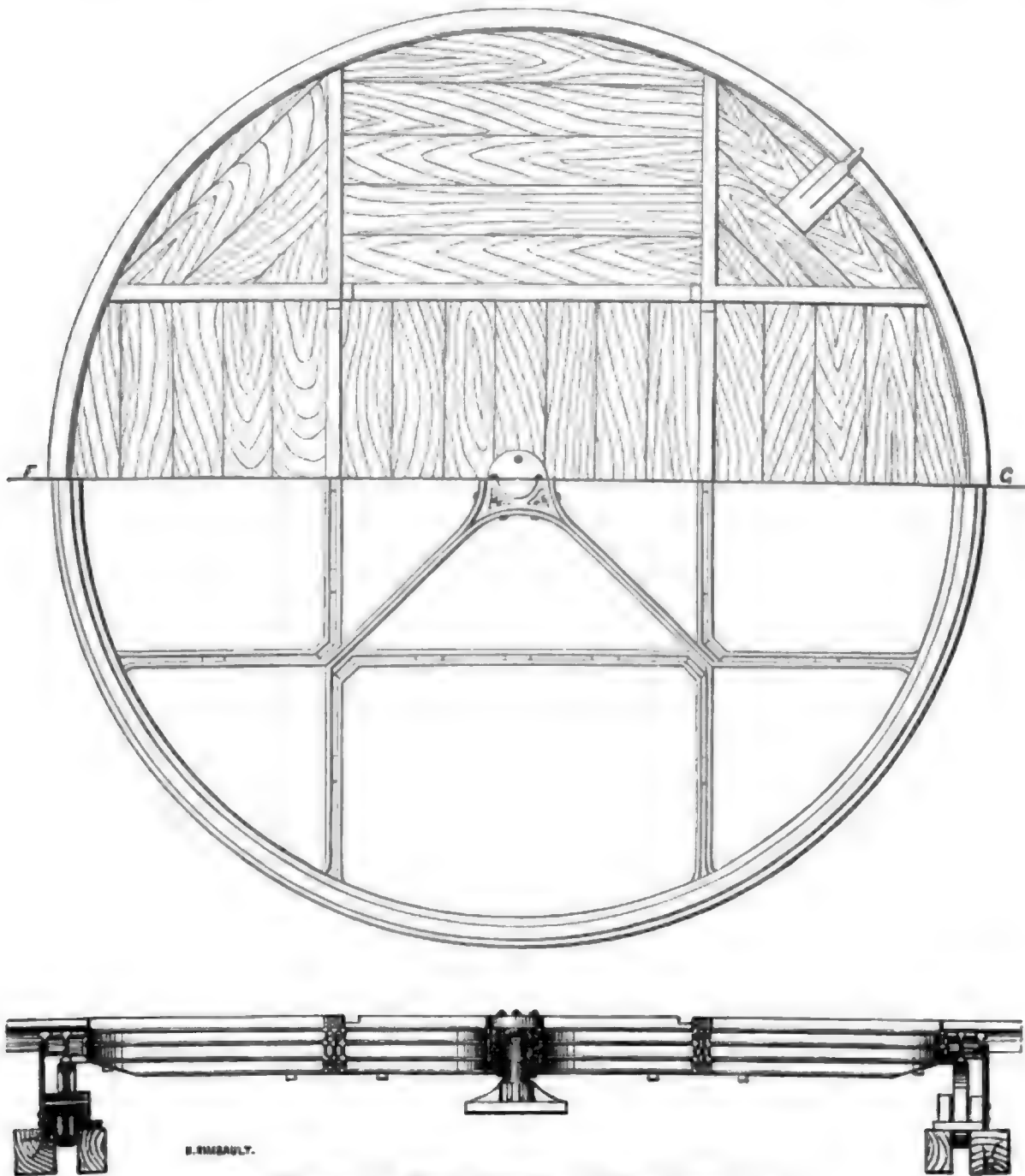
CROSS SECTIONAL ELEVATION



42 tons equally distributed on six wheels. The first engine-weighing table erected in England was placed at Crewe station, by Messrs. Pooley & Son, in 1847; to which the tables exhibited in 1851 were similar, having only one table to weigh a pair of wheels,—three tables and three steelyards for a six-wheeled engine.

In the machine of 1862, the independent table allotted to each wheel admits of weighing the engine, and adjusting the springs and the loads on the rails through each wheel, at one operation. But this refinement of detail demanded greater nicety of manipulation, as in weighing a body like an engine resting on stiff

FIG. 33.



WROUGHT-IRON GIRDER TURNTABLE, by Messrs. Baines & Co.

springs, it is obvious that, in the first place, the bearing surfaces of the rails on which the engine is to be weighed must, when unloaded, range in a true level plane,—longitudinally and transversely; and secondly, that when the engine to be weighed rests on the machine, the descent of the tables in the act of weighing must be equal and simultaneous. If the tables do not do so, then one or more of the springs of the engine will be relieved of part of their load, which will be transferred to the remaining springs,—

thus causing a double error, which has been found in practice to affect the indicator as much as 7 cwt., with $\frac{1}{8}$ inch difference of level. This is easily understood when it is known that some engine-springs deflect only $\frac{1}{4}$ inch per ton of load, and others not so much. The sensitiveness of the machine has induced some engineers to prefer the old three-table machine; nevertheless, the six tables are preferable, as they supply a useful test of the quality of the springs, and Mr. Pooley, in order to ensure the unison of

action which is indispensable for correct measurement, or indeed for any measurement at all, has applied a "finger-shaft," placed longitudinally under the series of steelyards, which are arranged in three pairs, in a row; the finger-shaft carries half-a-dozen sliding arms, or "fingers," which can be brought to bear upon the points of the steelyards, pressing them down and blocking them simultaneously, or permitting them to rise simultaneously, at the will of the operator. In testing the distribution of weight on the wheels of an engine, the steelyards are in the first place blocked, then released by the operator at the finger-shaft. Should they fail to move at the same instant, or to move at all, the operator orders the springs of the engine to be tightened or slackened, as may be requisite, until by repeated trials he perceives the points of the steelyards rise simultaneously on being released,—showing that the appointed weight is incumbent on the rail under each wheel; thus the practical purpose of the machine is effected. At the same time, the actual distribution of weight may be ascertained by shifting the poises on the steelyards until the latter rise simultaneously, as before. The application of the "finger-shaft" to the six-table machine, superseded the attendance of six men, previously required for the manipulation of the steelyards.

The second novelty in Mr. Pooley's machine is to be found in the construction of the steelyard and its permanent poise. The steelyard in other machines is adjusted by means of adding to or subtracting from the weight of the counterpoise hung from the end of the steelyard. But he applies the adjustment permanently to the steelyard itself, by means of a fine screw inserted at the extremity of the longer arm, in connection with a brass slide, by which its proportions are changed according to changes of condition affecting the balance. The poise, or balance, is a sliding weight, made like a saddle to embrace the steelyard, a good fit, and slid by hand, to indicate tons by the scale on the steelyard. The poise carries an auxiliary or sub-poise, cylindrical, and made with a worm motion gearing into a rack on the poise. Each turn of the sub-poise advances it one tooth of the rack, to indicate hundredweights, and its circumference is graduated to indicate pounds. To save time in setting the sub-poise, it is so constructed that it may be slid over the rack when at the position of zero. Thus the ordinary loose or pendulous weights are superseded, and chances of error and delay avoided.

The third novelty consists in the solid form and arrangement of the levers and sustaining bearers below the table, which permit the transit, and carry the weight of heavy engines, without injury to the knife-edged centres of the levers; these are placed close to the extremities of the weighing rails, so that "tipping" of rails by the wheels of an entering or departing engine is prevented. Thus the ordinary relieving

apparatus, employed to ease the tables off their bearings, is dispensed with, and the tables are at all times ready for use. The proportions of the levers are such that 5 lb. at the end of the steelyard, 37 inches from the fulcrum, balances one ton on the table, giving a combined leverage of 1 to 448.

Messrs. Pooley & Son exhibited a weighbridge for wheeled carriages, in which the main fulcrum or bearings are carried by the iron frame or kerb, thus reducing the cost of foundations. It is fitted also with the same kind of steelyard and poise employed in the engine-weighing table.

A machine for weighing and preparing "piles" for railway bars is likely to prove useful to ironmasters, in substituting exact weight for guesswork. The top of the frame is like a miniature railway, with a weighing table, lever underneath, and a steelyard which can be set for the

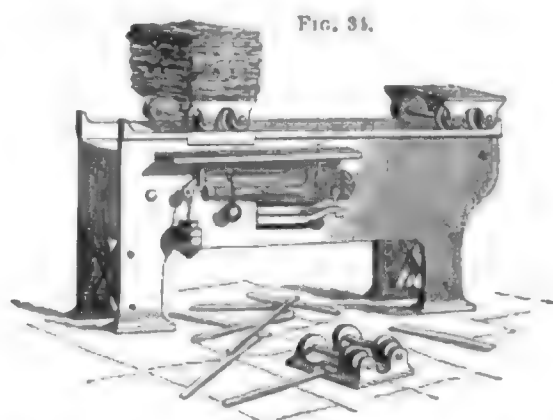


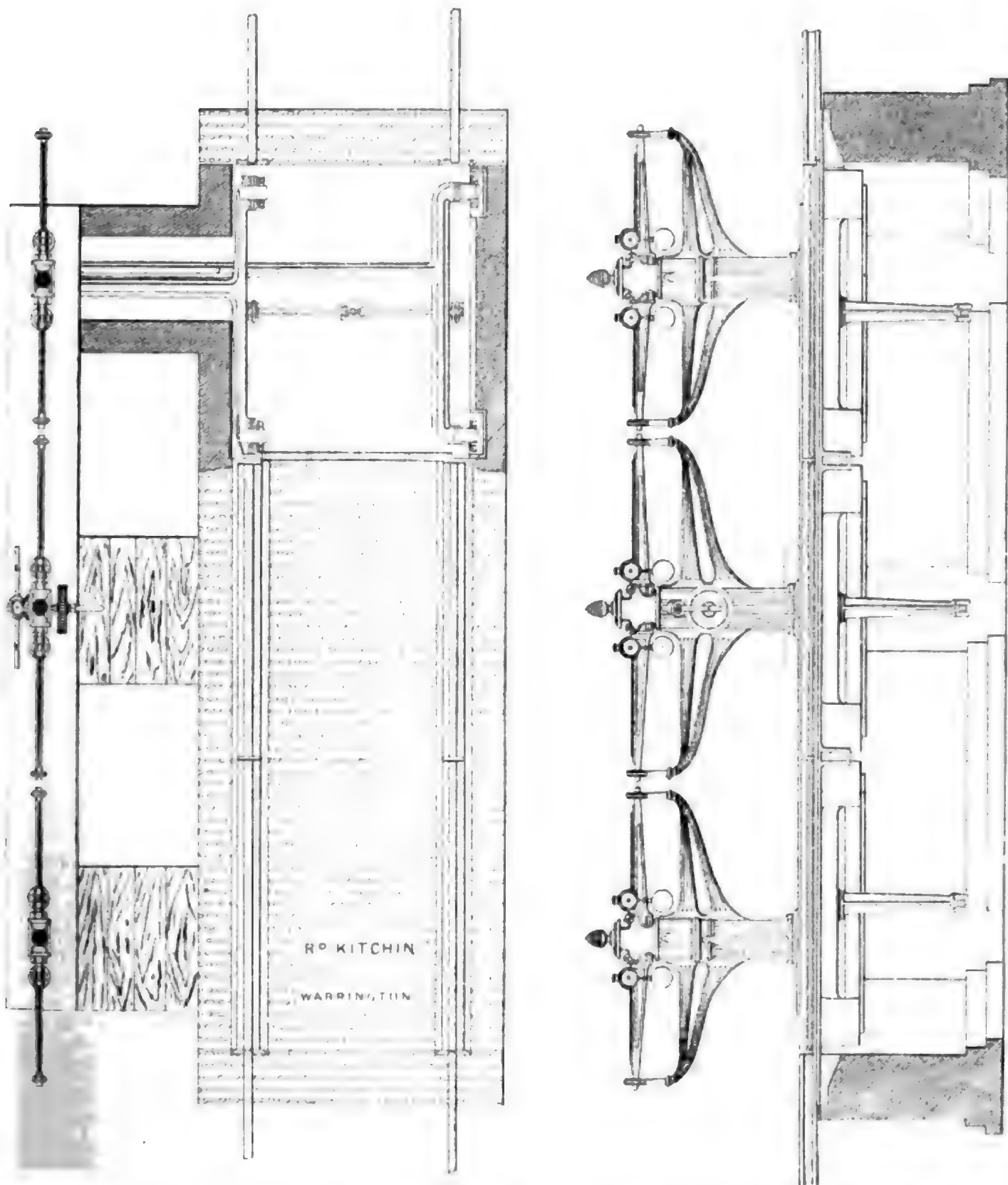
FIG. 34.
PILE-WEIGHING MACHINE, by Messrs. H. Pooley & Son; for weighing and preparing Piles for Railway Bars.

required weight of the piles. The piles are built on small trucks placed on the machine, and when weighed up to form a bloom, each truck is run off to the bloom furnaces (fig. 34). Other machines were exhibited, for weighing merchandise and parcels, and for the use of rolling-mills.

Mr. R. Kitchen, of Warrington, exhibited Hind's engine-weighing machine (Plate VI.). Like Mr. Pooley's, it consists of six tables, with six independent steelyards to weigh separately the weights at each wheel of a locomotive. The machine is "self-contained," being enclosed in, and attached to, strong iron framing, by means of which the cost of foundations is expected to become merely nominal.

The lines of rails on the tables are continuous, that is to say, they are applied end to end, without the intervention of the fixed pieces forming part of the frame in other machines. This is, perhaps, objectionable, as the bearing centres of the rails being bedded considerably within the ends of the rails, these are liable to tilt under a heavy-loaded wheel entering on them; and in order to avoid this contingency, a relieving apparatus is applied, the object of which is "to lay the

ENGINE WEIGHING MACHINE (HIND'S PATENT)
BY
MR RICHARD KITCHIN, SCOTLAND BANK IRON WORKS, WARRINGTON



SCALE 1/4 INCH TO ONE FOOT

whole system of weighing apparatus dormant when an engine has to go on or off, and to raise all, including the engine, to the weighing position, by one movement." The tables, when dormant, fit into bevilled seatings in the frame, to remain firm and steady when an engine passes over, and to exclude water and dirt. The steelyards are made to indicate tons, hundredweights, quarters, and pounds, by one operation; they have a pendulous ball for the poise, hung from a circular disc, with extremely minute divisions, indicating pounds, and shifted by being turned on its axis, which carries a pinion that gears into a rack on the steelyard.

Hind's weighing-crab was also exhibited by Mr. Kitchin. It is an ordinary hoisting arrangement for overhead travelling cranes, adapted to weigh goods in suspension, fitted with a relieving apparatus and a steelyard, to indicate the weight by one operation. This crab will prove useful at railway stations and in large works, where weights are required to be registered.

Messrs. Catenot, Beranger, & Co., Lyons, exhibited a machine for weighing locomotives. The steelyards are scattered,—in two lines six feet apart,—and require six men to attend them in weighing an engine.

Messrs. L. Sagnier & Co., Paris, exhibited a six-table machine to weigh locomotives, up to 48 tons. It is made with a scale to each steelyard, to carry heavy weights, with an additional scale above the other for the measurement of less weights. There is a tender weighing machine, to weigh 20 tons.

Messrs. C. Schember & Son, Vienna, exhibited a machine to weigh the load on one pair of wheels at a time, with one table and two steelyards. As the fulcra are not under the rails, but beside them, at a little distance, the indications cannot be depended upon for exactness, the weight on one rail being in a position to affect the steelyard of the other.

Signals.—Messrs. Stevens & Son, London, exhibited their well-known semaphore signal. The pillar is constructed of iron lattice-work, combining strength and lightness; it is fitted with chains and pulleys for elevating the lamps, instead of ladders; compensating "pull-over levers," for working auxiliary signals, which are stated to be certain at a distance of a mile (fig. 35).

Messrs. Richardson & Chattaway, London, exhibited their train-signal, to enable the guard to communicate with the engine-driver; it comprises a mode of adjusting the weight for taking up the slack of the signal-cord.

Level-crossing Gates.—Messrs. Bain, M^cNicol, & Young, of Edinburgh, exhibited a set of simultaneous-acting level-crossing gates, turned by endless chains underground.

Mr. A. Vickers, of Bristol, exhibited a pair of level-crossing gates, worked by worm-gear, with shafting and mitre gear to the back styles.

FIG. 35.



SEMAPHORE SIGNAL, by Messrs. Stevens & Son, London; for Railway Stations.

II.—MACHINERY FOR MANUFACTURING TEXTILE FABRICS.

SECTION I.

MACHINERY FOR THE PREPARATION AND SPINNING OF COTTON.

CHAPTER I.

INTRODUCTION.

THE general interest manifested in the display of machinery in motion, for the manufacture of cotton in the Western Annex, was heightened by the universal consciousness of the great crisis in the cotton industries, which has stopped the ordinary supplies of the raw material from the Southern States of America, and has resulted in the enforced idleness of nearly half a million of our fellow-countrymen. Sea Island cotton stands highest in the estimation of English mill-owners, on account of its great length of staple, and its superior cleanliness; and it is used for the finest qualities of yarn. But good and middling Orleans cotton was, previous to the commencement of the war in the States, the most largely consumed. Since that time, Egyptian cotton has been substituted for Sea Island, and East Indian for Orleans. In connection with the demand for Indian cotton, general attention has recently been directed to India for the production of that article; and though Indian cotton was open to the objection of shortness of staple,—yet, when our manufacturers made it their business to look the difficulty in the face, it was found quite possible—and it was proved perfectly practicable at the Exhibition—to work up staples of the shortest sorts. In fact, the necessity of dealing with Surat cotton, and making the best of it, has caused people to learn to spin. “Twenty-fours” was the finest count they were in the habit of spinning from Surat staple, with a loss of material by waste amounting to 25 per cent., sold for manure at a shilling a ton; they can now successfully spin an excellent round thread of double the fineness—“fifties” is the count—and there is very little doubt that, with the aid of improved cultivation, if the inducement continues, “sixties” and “seventies” will be reached in time. A writer in the “Cornhill Magazine,” for November,

1862, is so sanguine of the capabilities of the Indian staple for improvement, that he confidently predicts it will rival in every respect the staple which is in such high repute with English manufacturers. In support of his prediction, he instances the successful experiments of an English gentleman who had visited Nagpore for the purchase of cotton, and who purchased on his own account from the native cultivators a field of a few acres extent, in which the cotton plants were just breaking through the earth. He had his plants carefully weeded and pruned, and the soil at the roots loosened and watered when needful. The result of this judicious treatment was that the plants yielded treble the quantity of cotton produced on his neighbours’ fields, with a longer and stronger staple. His second year’s crop, grown from the most promising seed of his first crop, yielded a supply of cotton, “in every respect equal to the best New Orleans, and surpassing it in delicacy and brilliancy of colour.”

The length of staple not only varies for different kinds of cotton, but varies also in the same kind. Thus, Sea Island cotton varies from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in length of staple; New Orleans cotton varies from 1 to $1\frac{1}{2}$ inch; and Surat cotton varies from $\frac{3}{4}$ to 1 inch in length of staple.

Although there are several varieties of cotton produced in India, including that raised from Sea Island, Egyptian, and New Orleans seed, there are but two recognized descriptions of cotton exported to England: the Dharwar cotton, partly raised from exotic seed; and “Surats,” which comprehend generally every kind of indigenous cotton. The saw-ginned cotton of Dharwar has long held a favourable place in the Liverpool market. It is commonly supposed to have been raised from New Orleans seed, and though it is so only in part, there is no doubt that the best cotton from Dharwar is grown from the best Orleans seed; and it would be still further improved in quality if cleaned in the Macarthy gin. The chief defect of all,

that has militated against the use of Indian cotton in England, is the foul and adulterated state in which the raw material is baled for exportation. In addition to the impurities which have adhered to the cotton, either in the field, in its culling, or in its removal, every broker, weigher, or packer, through whose hands it passes, filches a pound or so as his perquisite, and makes up the weight with some foreign substance. To correct this, the cotton must be grown under European superintendence; the European would be but serving his own interests in seeing that the cotton he purchased was clean and pure; and, when packed and screwed by him, the chances of deterioration in transit to the port of shipment would be avoided. In fact, it is reported that strong measures are now being adopted by the Indian Government—sensible of the enormity of the abuse—to prevent adulteration, and that a staff of cotton inspectors has been appointed.

The first process in the manufacture of cotton is the separation of the seed, by means of gins, from the staple, to which it is intimately attached, converting seed-cotton into cotton. The next process is to clean and open the cotton, which arrives at the mill in bales, in a highly-compressed condition, by means of scutchers, beaters, and ventilators,—being the first stage of preparation, which delivers the staple in bales or fleeces of even consistency. In the third process, the cotton is carded; that is to say, the fibres are drawn out and laid straight and parallel, and delivered in the form of slivers, or bands of cotton. Fourthly, the slivers are doubled and drawn repeatedly, in order, by thus mixing the staple, and averaging the defects, to equalize the substance and consistency of the slivers, and to range the fibres perfectly straight and parallel. Fifth, the sliver is delivered to the slubbing, roving, and spinning machines,—throstles or mules,—by which it is repeatedly doubled, drawn, and twisted, until it is converted into thread, and wound upon bobbins or spindles. The thread is next prepared for being woven into cloth in looms, and is subjected to various treatment, to suit the requirements of the manufacturer.

The oldest machines for cleaning cotton are the Indian churkas, of which one was exhibited by Messrs. Platt Brothers & Co. They are still used by the natives in India, and have probably remained without material improvement or modification for two thousand years. In the Indian churka, two wooden rollers, $\frac{3}{4}$ inch diameter, and from 6 to 12 inches long, are placed together in a wooden frame, and they work together, with spiral-cut teeth cut out of the ends, to gear with each other. The machine is turned by one hand and fed by the other: the seed-cotton being handed to the rollers, they seize and draw through the staple, delivering it on the other side; and they reject the seed and a great portion of the impurities, which fall down on the feeding side.

It is said that, with the common churka, the natives gin upwards of seventy-five per cent. of the cotton produced in India; and that it usually takes twenty persons to produce 1 cwt. of clean cotton per day, or about $9\frac{1}{2}$ lb. per hour,—less than half a pound per hour for each person! Such is labour in India!

The pressing need of improvements in ginning processes, to meet the wants of the trade, led to the invention, about the year 1790, by Mr. Eli Whitney, of the State of Georgia, of his well-known saw-gin, which at once enabled the producers of cotton to keep pace, in cleaning it, with the demand of the times. An immense stimulus was thus given to the cotton-producing power of America: the production in the United States alone rose from 138,000 lb. in 1792, to 1,600,000 lb. in 1793, which was further increased two-hundred-fold—to 32,500,000 lb.—in 1802, ten years from the date of the invention. In 1860, the cotton crop of the United States amounted to the nearly incredible quantity of 4,000,000 of bales of 500 lb. each, or 2,000,000,000 lb.

It is a noteworthy fact that the cotton-gins in general use in the States are facsimiles of the original Whitney gin, notwithstanding many inventions that have been designed to improve upon or supersede it. This gin contains about fifty or more circular saws mounted about an inch apart on a cylinder turned by a fly-wheel. Another cylinder mounted with brushes, and working in an opposite direction, clears the cotton from the teeth of the saws. It is stated that one man with a two-horse-power engine can clean with Whitney's eighty-saw machine 5,000 lb. of seed-cotton per day of fourteen hours. As the clean cotton averages twenty to thirty per cent. in weight of the seed-cotton, the machine would produce 1,250 lb. of clean cotton per day, or about 90 lb. per hour. It is nevertheless objected to the Whitney gin that it injures the staple. The machine was specially adapted for the strong short-staple cotton, with a large green seed and tightly-clinging fibre, usually known as New Orleans, or more properly the Mexican green seed variety. Whereas, for the long, fine, and delicate varieties, as Sea Island or Queensland, or the small native staples of India (the Surats), the Whitney gin has been found comparatively worthless. It did considerable injury to the fibre in the process, and materially depreciated it. The recently increased cultivation and growth of cotton in other parts of the world has so increased the demand for gins at home as to have called the attention of English machinists specially to their improvement and construction.

Until within the last twenty years, little attention has been devoted to the improvement of the carding engine. Cards are to be found at work in some of the fine-spinning mills in Manchester which were made more than sixty years since; and these cards, though they turn off good work,

do very little of it, and they require a considerable degree of attention, several attendants being constantly employed in stripping both the flats and the main cylinders. In a mill having a hundred such carding engines, six men are constantly engaged from morning to night, going the round of the cards, stripping a flat at a time. Stripping is a most important work, and requires close supervision, for if the impurities and fibres which collect at the roots of the wire-brush or card be not cleaned out, the cards become choked up,

and they cease to operate effectively upon the cotton submitted to the carding process. Stripping should be performed regularly and uniformly; when it is done at intervals, the quality of the cotton delivered from the card varies according to the frequency of stripping and the cleanliness of the cards.

The number of factories, spindles, and looms, and of persons employed in the spinning and weaving of cotton, in 1861, as shown by official returns to Parliament, were as follows:—

STATISTICS OF THE COTTON INDUSTRY IN 1861.

LANCASHIRE.	Number of Factories.	Number of Spindles.	Number of Looms.	POWER.		NUMBERS EMPLOYED.		
				Steam.	Water.	Males.	Females.	Total.
Spinning only	727	11,072,899	.....	H. P. 73,284	H. P. 1,319	37,571	42,876	80,447
Weaving only	571	.....	116,446	13,627	183	22,077	34,552	56,629
Both Spinning and Weaving	565	10,457,633	189,977	113,326	1,828	73,877	98,129	172,006
TOTAL IN LANCASHIRE	1,863	21,530,532	306,423	200,237	3,330	133,525	175,557	309,082
TOTAL IN ENGLAND.....	2,472	28,351,645	366,822	259,163	9,112	170,167	223,762	393,929
TOTAL IN SCOTLAND	138	1,845,686	30,110	13,919	2,332	7,208	28,859	36,067
TOTAL IN IRELAND	9	119,944	1,757	909	290	824	1,910	2,734

The machinery employed in the manufacture of cotton into cloth naturally divides itself into three departments,—preparing, spinning, weaving. The machinery for preparing and spinning is constructed by one class of exhibitors, whilst the weaving machinists, with one exception—Messrs. Platt Brothers & Co.—constitute a distinct class of exhibitors. It will be convenient, therefore, in noticing the machinery for the preparation and spinning of cotton, to examine and dispose of, in succession, the different groups of machines exhibited,—making no attempt at a more specific classification;—and they will be taken in the order in which they were placed in the Western Annex, commencing with Messrs. Walker & Hacking's machinery.

CHAPTER II.

MACHINES EXHIBITED BY MESSRS. WALKER AND HACKING, BURY.

Messrs. Walker & Hacking exhibited an entire series of machines arranged for coarse numbers, including two throstles and two mules.

1. *Cotton Opener*.—The cotton to be delivered into the opening machine, should, in the first

instance, be carefully mixed from the various bales selected for reduction; and with Surat cotton, careful mixing is, perhaps, of more importance than with any other. When properly mixed, the staple can be more evenly drawn, and will yield a stronger and rounder thread than when the mixture is imperfect.

The opener has one toothed cylinder, and one beater. The cotton to be opened being spread evenly upon the travelling "creeper," or endless lath frame, is conducted to a pair of iron fluted feeding rollers, which are sufficiently weighted to prevent the cotton from being snatched off in too large pieces; having passed through the rollers, it is struck by the teeth on the cylinder, making 550 revolutions per minute, and is separated in small portions, from the fibres of which the impurities are loosened. The heavy impurities, as husks and sand, are allowed to fall through a grid which encircles the cylinder below; and the cotton passes over and is delivered upon a pair of perforated zinc cylinders by means of the draught occasioned by the exhaustion of air from the zinc cylinders by a fan. The cylinders revolving at a low speed, carry forward the cotton between them, and deliver it in a connected fleece or sheet to the second pair of feeding rollers, which present it to the beater revolving at about 1350 times per minute. By the beater, the cotton is still further loosened

and the fibres separated, and an additional quantity of heavy impurities is discharged through the second encircling grid. The cotton is again drawn, by means of a fan-draft, against and between a second pair of perforated cages, and again delivered in the form of a fleece, when it is discharged over and through three calender rollers, to compress the fleece into a "lap." The lap is taken up on the lap-roller, which is slightly conical, so that it may be readily withdrawn from the lap when the latter is made up to the size required. To ensure the regular and uniform winding of the lap on the lap-roller, it is rested in the hollow between two fluted rollers, which, moved at a constant speed, draw forward the lap, which is passed between them and the lap-roller, and is taken up by the latter at a uniform circumferential speed. Still more to compress the lap, and economise bulk, a pair of racks are hung, one from each end of the axle of the lap-roller, which gear with pinions on a brake-shaft, having a friction-wheel, on which the strap may be tightened to regulate the resistance to the ascent of the lap-roller as the roll enlarges upon it, and thus to produce a firm and compact roll of lap. When the lap reaches the required weight—usually about 40 lb.,—a self-acting stopping motion suspends the delivery, and the lap-roller is withdrawn to make way for an empty roller.

This opener is designed for working both Indian and American cotton. The toothed cylinder is 37 inches in diameter, and carries six ribs on the circumference, armed with teeth 2 inches in length, $\frac{7}{8}$ inch thick, and $\frac{1}{2}$ inch apart; so formed with flat faces as to open the cotton without stringing it. If the teeth had only been half as broad and twice as many, they would probably have been more effective in accomplishing the object in view, which is to completely separate the fibres of the cotton and rid it as much as possible of dirt. The feed rollers are placed $\frac{3}{4}$ inch clear of the cylinders, near the upper side, to obtain an extensive cleaning surface. The width of the spaces between the grid-bars may be varied according to the nature of the cotton to be opened. The beater is 18 inches diameter, and has four knives or blades set $\frac{1}{4}$ inch clear of the feed rollers; by this means the cotton can be made into a lap for the scutcher, at the finishing end. This machine is said to be capable of opening from 25,000 to 30,000 lb. of cotton in 58 hours, including sufficient time for cleaning it; but it is questionable whether it can wind into lap more than half that quantity.

2. Single Scutcher, with Lap Machine.—This scutcher, 40 inches wide, consists of one beater, 16 inches diameter, with three blades, and an inside fan with down-draught. The laps from the opener are placed, three at a time, in succession, upon the travelling creeper, on which they are kept in position by rods passed through them and into guide-slots in the side-frames. They are unrolled one over the other, so that three

thicknesses of lap are conducted to the feed-rollers, weighted as in the opener, which deliver the lap to the beater. The blades of the beater are set $\frac{1}{4}$ inch clear of the rollers, and make 1,600 revolutions per minute. To ensure a uniform thickness and weight of lap, Lord's patent feed-regulator is attached to the machine. It operates by varying the velocity of the feed-rollers inversely as the total thickness of lap passing between them, so that the thicker the lap the slower is the feed; and the cotton is delivered to the beater at a uniform rate—1 lb. per yard run for twenties count. To vary the speed of the feed-rollers, they are driven by means of a band working over two vertical conical drums, on which the position of the band is shifted, by means of a direct connection, simultaneously with the rising and falling of the upper feed-roller upon the lap. The speeds of the rollers are thus simultaneously regulated to the thickness of the lap passing between them.

The heavy impurities loosened from the staple find their way, as before, through the grid, and the cotton is drawn forward, as before, to the perforated zinc cylinders, and rolled into lap. The cotton is passed and repassed three times through this machine, for the purpose of being thoroughly beaten and cleaned. The machine is fitted with a stop-motion, like the opener.

3. Single Carding Engine.—This engine is of the usual sort, having one main iron cylinder, 45 inches diameter, with seven iron rollers 6 inches diameter, and six iron clearers $3\frac{3}{4}$ inches diameter. The taker-in cylinder is 9 inches, and the doffing cylinder is 22 inches diameter. The working surfaces of these cylinders and rollers are covered with cards, or fine steel-wire thickly set in sheets of leather, woollen cloth, india-rubber, or india-rubber cloth, for the purpose of thoroughly separating the staple, fibre from fibre, and straightening it.

The carding engine is supplied with laps from the scutcher, which are fed into the licker-in in this machine by means of one roller and dish. The "dish" is, in fact, a segmental edge on the feeding plate, on which the lap passes under the roller; and the feeding-edge carries forward the lap close to the surface of the licker-in: more closely than could be done by the agency of a pair of rollers. Underneath the licker-in, which seizes the cotton as it is delivered from the feed-roller, there is placed a strip of iron, planed to a straight edge, which may be set to any angle with the surface of the licker-in, and which separates a portion of the husk and other impurities which may yet cling to the cotton, and would otherwise pass over into the cylinder. On the other side of the cylinder there is another and similar strip of iron applied at the surface of the cylinder, in advance of the last roller, with a ledge fixed at its lower edge, to intercept and retain the shale, leaf, or other matter, which would otherwise pass on the

doffer, from which the cotton is delivered, and would be carried off into the sliver. This striping-plate would be of service in all carding engines. The cotton is taken from the doffer by means of a comb or toothed steel plate, which is caused to reciprocate in front of, and tangentially to, the surface of the doffer, removing the cotton in a light fleece the full width of the doffer. The fleece is contracted and drawn through a tube by means of a pair of rollers, which deliver it, in the form of a sliver about $1\frac{1}{2}$ inch broad, into a cylindrical tin can. That the sliver may be deposited regularly and compactly, the can is turned on its axis, with a slow revolving motion. The combing motion for the doffer is new, eccentrics being substituted for the usual crank motion. The working journals of the comb-stock are of cast iron, in cast-iron bearings. The manner of lifting the catches for holding up the cover is novel: the shaft usually placed across and above the cover, is placed underneath, which leaves the space free for receiving a lap on the top of the machine,—sometimes very convenient. This engine is stated to be capable of carding 500 to 600 lb. per week.

4. Drawing Frame.—This machine is one of three heads and six deliveries. Its function is to straighten the fibres, and to average and equalize the substance, of the slivers brought from the carding engine. For this object, six card-slivers are passed in at one head of the machine, joined into one, and at the same time drawn out or extended to six times their length, and the resulting sliver delivered at the other side of the machine is, in composition, an average of six card-slivers, and of the same weight or substance per yard. This operation is repeated through the second and third heads; and the final sliver is therefore the average of $6 \times 6 \times 6 = 216$ card-slivers, and its fibres are straight and parallel. But, too much “doubling” and drawing of short cotton is injurious to the weaker staples.

The drawing process is performed by the agency of four pairs of rollers, revolving at different speeds, through which the slivers are passed. The lower rollers are of iron, in a row; the back or first roller is coarse-fluted. The “top rollers” are placed over them. The back top rollers are fluted like those below, in order to pull in the sliver uniformly. The other top rollers are covered with strong woollen cloth specially prepared, and covered with varnished sheep-skin. The top rollers are on Mr. Evan Leigh’s system, the peculiarity of which is that the rollers, which are placed in pairs on short shafts, turn on the shaft independently of each other, like loose wheels on one axle, that the slivers may pass freely under the rollers, without being liable to the abrasion or other injury which formerly arose from inequalities of size in the rollers, when fixed on one shaft. They are heavily loaded with suspended weights, and are sustained

by the lower rollers, so that the slivers are firmly held between them, and prevented from slipping through under the drawing action. The first pair of rollers moves slowly, and each succeeding pair moves faster, the front or finishing rollers making 450 revolutions per minute. Thus, the sliver is partially drawn in three successive stages between four pairs of rollers.

This drawing-frame is fitted with the usual stop-motions at the back and the front, to stop the machine when any one of the slivers breaks accidentally. The slivers, when whole, pass over and are borne by “tumblers,” or unbalanced levers, one to each sliver, which “tumble” when the slivers break and release them, and in tumbling, come into contact with a catch, which by releasing a spring throws the driving-belt on to the loose pulley. The frame rests until the attendant fixes the sliver, restores it in position, and again sets the machine in motion. There is another stop-motion to act when the receiving cans are filled, which is new, and is seldom applied by other makers. This is a useful motion: without it, a great deal of waste occasionally takes place, by the sliver overrunning the can in the absence of an attendant. The front part of the frame is cased up in a neat and compact manner; the casings may be easily taken off and replaced, without the aid of a screw-key.

5. Slubbing Frame.—This is a frame of thirty-two spindles. In the slubbing-frame the sliver is, for the first time, twisted. It is also drawn, by means of three pairs of rollers. First drawn; then twisted, by the revolution of the flyer, but as little as is practicable, to give just sufficient strength or cohesion to keep the sliver,—now called “coarse roving” or “slubbing,”—from breaking, whilst it is passed down the tube of the flyer and wound upon the bobbin. The draft should not exceed 5 inches for each inch of the sliver. The bobbins are carried on spindles concentric with the flyers, and their speed is reduced in proportion as the bobbin gets filled, and the diameter of the roll of slubbing is increased. Thus, a uniform tension is maintained upon the slubbing, between the drawing rollers and the bobbin. A full bobbin, 5 inches diameter and 10 inches long, is made on this frame, containing a pound of slubbing, 840 yards in length, for twenties to twenty-fours counts.

6. Intermediate Frame.—The purpose of this frame, intervening between the slubbing and the roving frames, is to get a doubling on the roving before it enters the roving frame. Two slubbings are passed through the rollers, and drawn into four times their length; and they are united in front,—forming thus a roving of half the weight per yard of the slubbings, with more nearly an equality and evenness of substance. It is, as before, additionally twisted, and wound on a bobbin by the agency of the flyer.

7. *Jack Frame, Fly Frame, or Roving Frame.*—In this frame the rovings are again doubled, drawn, and twisted.

8. *Throstles.*—The throstles, or throstle-frames, were originally called water-frames, from the circumstance that the first frames were driven by water-power; and having always been employed for spinning warp-yarns, the yarn produced by the the throstle is bought and sold under the name of "water-twist." The throstle of the usual kind, exhibited by Messrs. Walker & Hacking, is 3 feet wide; it has three pairs of rollers, between which the rovings are passed and drawn. The draft should not exceed 7 inches per inch of the length of the roving. The frame is mounted with spindles and flyers as in the frames previously described, making 5,500 revolutions per minute; but whereas, in the others, the bobbins must be driven by gearing separately from the gearing for turning the spindles, the thread spun by the throstle-frame as it leaves the flyer has sufficient strength in itself to drag the bobbin about its axis, keeping itself taut, at the same time winding itself on the bobbin. No special gearing, therefore, is provided for turning the bobbins; and, that the bobbins may drag with the proper degree of frictional resistance to keep the threads taut, and make compact bobbins, they are supported on and revolve upon washers of cloth or leather of suitable roughness. Thus, finally, the bobbins revolve with a velocity at the circumference measured by the difference between the revolving velocity of the flyer and the length of thread delivered through the flyer. The throstle is only adapted for spinning numbers from, say, fifties downwards to coarser numbers, as there must be a certain degree of strength in the thread to drag the bobbin, which is not always to be found in finer numbers. The finer or higher numbers are spun by the mule.

The throstle now under consideration is provided with plates for covering the feet and collars of the spindles—one set of plates on the bottom rail, another set on the top rail. The plates prevent oil getting on and spoiling the washer-cloth, and destroying the drag of the bobbins; they also prevent fly or dirt getting into the eye of the footstep, which works for three days without oiling; otherwise requiring to be oiled every day. These plates are raised at once by one handle; they are good and serviceable appliances, and are worthy of imitation. The throstle has also an improved rack for regulating the lift, which can be done with great facility, and without stopping the machine.

In Hall's new throstle, also exhibited by Messrs. Walker & Hacking, the chief object is to dispense with the "doffers,"—a class of attendants, consisting of boys and girls, required for removing, or doffing, the bobbins from the spindles when filled with yarn. The ordinary throstle must be stopped while the bobbins are

being doffed, which of course causes a loss of time while standing, and demands a large attendance of doffers. To save these contingent expenses, the flyers, in Hall's throstle, are made with long tops about 5 inches in length, and run in two bearings. The driving pulley of the flyer is fixed on the upper end of it. The flyers and spindles lie over at an angle, not vertically as in the ordinary frame, and thus they can be more directly driven, and with a longer band, which ensures more nearly positive driving. The spindles are slit at the tops, and the bobbins are fitted into the slits, so that the yarn drags both the bobbin and the spindle round. The drag is regulated by means of a tape passed over and under each spindle with tightening screws. The bobbins do not rest on rails as in the ordinary frame, and the washer-cloths are dispensed with. As the frame may be doffed by the spinners while it is in motion, the spindles not being connected with the flyers, the attendance of doffers is dispensed with. With these advantages there are drawbacks. When a thread is broken, a small iron hook must be used to pass the thread through the eye of the flyer, which consumes much more time than in other frames. The frames, being 4 feet wide, take up more room than others, and space is an important consideration in setting out a mill.

9. *Parr's Self-acting Mule.*—The mule which is exhibited is adapted for spinning cotton yarns of middling qualities. It has three pairs of drawing rollers, to reduce the roving to the size of the finished thread. The rollers, the carriage, and the spindles, commence to move at the same instant,—the rollers delivering the roving at a given speed, the carriage recedes from the rollers at a speed calculated to maintain a proper tension on the thread between the delivering rollers and the spindles in the carriage, and the spindles are driven at a uniform speed, for the purpose of twisting the roving, as it is delivered, into a hard fine thread of the desired fineness or "count." The speed of the spindles determines, to a very great extent, the quantity of yarn that can be produced in the mule, as, indeed, in the other spinning frames; as the time required to give the required degree of twist, by the revolution of the spindles, determines the rate of production. The rate at which the carriage recedes is regulated in the same way. The usual travel of the carriage is 62 to 64 inches at a stretch. In Parr's mule the stretch is 64 inches, and this is the length of thread made at one stretch. At the end of the stretch the carriage is stopped by shifting the driving-belt from the fast to the loose pulley; the rollers are stopped at the same time by being thrown out of gear through the medium of catch-boxes; and the spindles are stopped and reversed, or "backed off," by means of a friction-box put in gear, which is connected with the spindles by the "rim-band." The next move-

ment is to wind the stretch of thread upon the spindle, at a given speed, in proportion to the increase of diameter of the partially-formed cop, and at a proper tension to impart solidity to the cop. For this purpose, the motion originally invented by Mr. Richard Roberts is employed: the carriage is drawn in by means of the scroll-pulley, put in gear by means of a catch-box; a band or rope, connected to the carriage, is lapped round the pulley, and draws the carriage home; then the catch is thrown out, and another put in gear to take the carriage out again, in a similar manner, by means of a band. The top faller is connected with and moves on an inclined plane, called the shaper-plate, which guides the faller, and causes it to descend, guiding the thread on the bobbin, in obedience to the form of the plate. For turning the spindles, a drum on the scroll-pulley shaft is in gear with the mechanism that reverses the spindles while the yarn is backed off; a chain is fixed by one end to the drum, and by the other end to a radial arm of the quadrant, describing an arc of a circle. As the carriage recedes, and with it the drum, the chain is uncoiled from the drum, the drum revolves, and it turns the spindles to wind on the yarn. As the diameter of the cops increases, fewer turns of the spindles are required, and therefore a shorter length of chain is to be uncoiled from the drum. To effect this diminution of length or action of the chain, its point of connection with the quadrant is shifted nearer to the centre, and its traverse is therefore reduced in the same proportion.

Parr's mule is a good machine, and is simple in construction. The main driving-shaft, being low, admits of long driving-band. The arrangement for drawing out the carriage is designed to prevent the wheels and bands which draw out the carriage from breaking when unusual impediments fall in the way of the carriage as its motion ceases. The changes are positive, being effected by gearing instead of frictional apparatus. The winding on of the yarn is more positive than in most other mules, as the quadrant is driven by gearing instead of bands.

10. *Smith's (or Scotch) Self-acting Mule.*—This mule is better known by the name of the mangle-wheel mule. It is a stripping-mule; that is to say, the coils are stripped or thrown off the spindles, not backed off. That movement occupies less time than the backing off, but it acts injuriously on the yarn, breaking many threads by the severe action; and it is best adapted for spinning coarse numbers, from sixes to thirties. Many mules on this plan, it is stated, are spinning as high as twenty-fours, running five stretches per minute. The advantages claimed for this mule are, 1st, that it can be driven from the main shafting, dispensing with countershafts: 2nd, the motion for drawing the carriage out and in, and squaring it, is positive, being worked by gearing; the

tin roller is driven by two bands, one at each side of the headstock: 3rd, the changes are positive, also the winding.

CHAPTER III.

MACHINES EXHIBITED BY MESSRS. JOHN HETHERINGTON AND SONS, MANCHESTER.

Messrs. Hetherington exhibited a series of machines arranged for coarse numbers, and a combing-machine for fine numbers.

1. *Single-beater Scutching Machine.*—The principal novelty in this machine consists in the management of the draught. The fan employed for exciting a current exhausts the air, as usual, from the interiors of two perforated-zinc cylinders, towards which the current is partially drawn up through the grid. But, inasmuch as this upward current opposes the free fall of solid impurities down through the grid, an additional opening for air is made in the cover of the beater, immediately over the feeding rollers, extending the whole width of the machine, protected by a perforated-zinc plate. An abundant supply of air is thus obtained to carry forward the cotton, and the draught is so directed as to aid the discharge of impurities under the beater, which is further facilitated by the extension of the grid in the lower part right up to the exhausting cylinders. Dampers are so placed inside the cylinders as to prevent the draught or entrance of air from the outer side, next to the delivery or lapping-up rollers; the cotton fleece is thus prevented from adhering too closely to the cylinders after it has been collected and delivered as a lap from the cylinders.

2. *Carding Engines.*—Messrs. John Hetherington & Sons exhibited three varieties of cards, fitted with recent improvements in self-acting appliances for continuously stripping. In the first carding engine, an American invention, the novelty consists in the application of two 8-inch rollers under the take-in, covered by wire brushes. The speed of the lower roller is subject to a regular variation, alternately faster and slower at the circumference than the main cylinder. Thus the cylinder is alternately stripped by the roller, and strips it, several times in a minute. With the intermediate roller, the cotton brought forward by the taker-in roller is partially carded, and the carded portion passes into the main cylinder. The remaining lumps are carried over and carded with the lower roller, from which and from the intermediate the remainder of the cotton is delivered to the main cylinder. The cotton is thus fed to the main cylinder in three well-opened layers, whilst a portion of the impurities is separated from the cotton before it is delivered to the main cylinder. A similar

driving band from the fast to the loose pulley ; a third cam places a bristle-brush into contact with the cylinder, underneath, to clear it ; the fourth cam applies a slow reversing motion to the cylinder by means of a friction-clip, or pad, applied to the surface of it. When the belt has been shifted by the action of the second cam, the cylinder continues running, by its momentum, until the ratchet-wheel has made another revolution, when it again moves the cam-shaft which applies the pad to the cylinder, and reverses it slowly ; the brush, driven at a quick speed, is applied to and cleanses the surface of the cylinder, and when the cylinder has made a complete revolution backwards over the brush, the cam-shaft is again moved, and restores the machine to working order. The construction of this card shows ingenuity and novelty of design ; there is, nevertheless, room for improvement in detail and in performance, which can no doubt be effected (fig. 36).

Hetherington's Self-stripping Carding Engine.

—This card is 40 inches wide ; it has three working rollers, two clearers, and eight flats ; and is particularly applicable for medium and high numbers of counts, say above sixties ; the flats, or top cards, have been found by experience to act better on cotton of good quality than any other form of wire-brush. Being stationary, they collect and retain the dirt thrown into them better than rollers, and they straighten the fibre more effectually. But the chief objection to flats has been the cost of keeping them in working order, as they very soon become choked, and require to be frequently stripped ; and unless this is done very regularly, there is, as already remarked, a variation in the quantity and quality of cotton turned off by the doffer, and consequently in the thickness of the sliver. The improvement in this card consists in the application of an automatic arrangement, by means of which the flats are regularly and effectually stripped, with less chance of damage to the wires than when stripped by hand labour. The flats are lifted in succession by suitable gearing, and turned right over so as to present their inner or card surface to a revolving cylindrical brush which traverses and strips the flat ; after which the flat is returned into its place. The axle of the revolving brush is carried on two long arms centred upon the cylinder-shaft, which oscillate backwards and forwards sufficiently to cause the brush to traverse the whole series of flats during each oscillation, and to strip them in succession, one at a time, for each oscillation. The flats are also lifted and replaced by means of the brush-frame, which, in moving one way, operates with its slotted extremity upon a small crank-finger fixed on one end of the flat, to lift and turn it over on its pivots ; its continued movement brings a small rack to bear upon and turn a toothed pinion on the other

end of the flat, by which it is reversed and replaced in its bed. With the aid of a ratchet-motion, the brush-frame is adjusted to lift each flat in succession. The fly is carried over by the brush after each operation, and stripped off by a comb, and deposited in a box at one end of the card, from which it is removed to be worked over again for lower qualities of yarn. The delivery of the fly may be regulated by an adjustment of the speed of the stripping mechanism, according to the quality of the cotton operated upon. This mechanism is thoroughly effective in stripping the flats and keeping them in good order.

3. *Combing Machine.*—This cleverly designed machine was invented by M. Heilmann, of Alsace. Its purpose is to remove short staple, motes, and dirt from the high-class long staple cottons, as Egyptian and Sea Island. The machine has six heads, and is fed from six laps of cotton, each lap consisting of fourteen slivers from the breaker carding-engine, doubled into a lap, 8 inches wide and 12 inches diameter. Each lap rests upon a pair of revolving lap-rollers, which deliver the end of the lap down an inclined surface guiding it to a pair of feeding-rollers,—the lower roller of steel, fluted, the upper one covered with flannel and leather in the usual way. These rollers move and stop alternately, about sixty times per minute, supplying the cotton by intermittent feeds. The cotton is delivered by the rollers between the open jaws of an iron nipper, which seizes a portion of the cotton, and being moved by means of a cam, carries it near to the revolving comb-cylinder, which has seventeen combs ranged on one part of its circumference. The combs are passed through the cotton, so as to remove all short or broken fibres and impurities, and lay the long fibres straight and parallel. The nipper is then withdrawn from the cylinder, and its jaws are opened to release the partially-combed fibres, which are then drawn or separated from the fleece by means of a leather-covered roller, which works for the purpose in contact with a fluted segment on the unoccupied part of the revolving cylinder, and with a fluted steel detaching roller. As the fibres are drawn apart, the uncombed ends of the separated fibres—namely, the ends which were held by the nipper—are passed between the teeth of a fine top comb, and the combing of them is thus completed. The rollers are next reversed, and carry the newly combed fringe of fibres to be overlapped upon and pieced to the combed sliver which is in advance. A continuous sliver is thus delivered at the front of the machine, where all the six slivers are united through the drawing head. The speed of the revolving cylinder is sixty revolutions per minute. The machine can deliver 120 lb. of cotton per week for two hundred and fifties count, or 180 lb. per week for one hundred and twenties.

4. *Drawing Frame*.—This machine has one head, with four deliveries, of four lines of rollers. It is well arranged, and is fitted with stopping motions for front and back. It is fitted also with an eccentric motion and hand lever, for relieving the rollers from the dead weights upon them while the machine is not at work. This is an important provision, and it is worthy of general adoption, as the dead weights hanging for long periods are likely to flatten the top rollers, which are covered with woollen and leather. When such is the case the leather is liable to be cut by the bottom rollers, and imperfect drawing is the result.

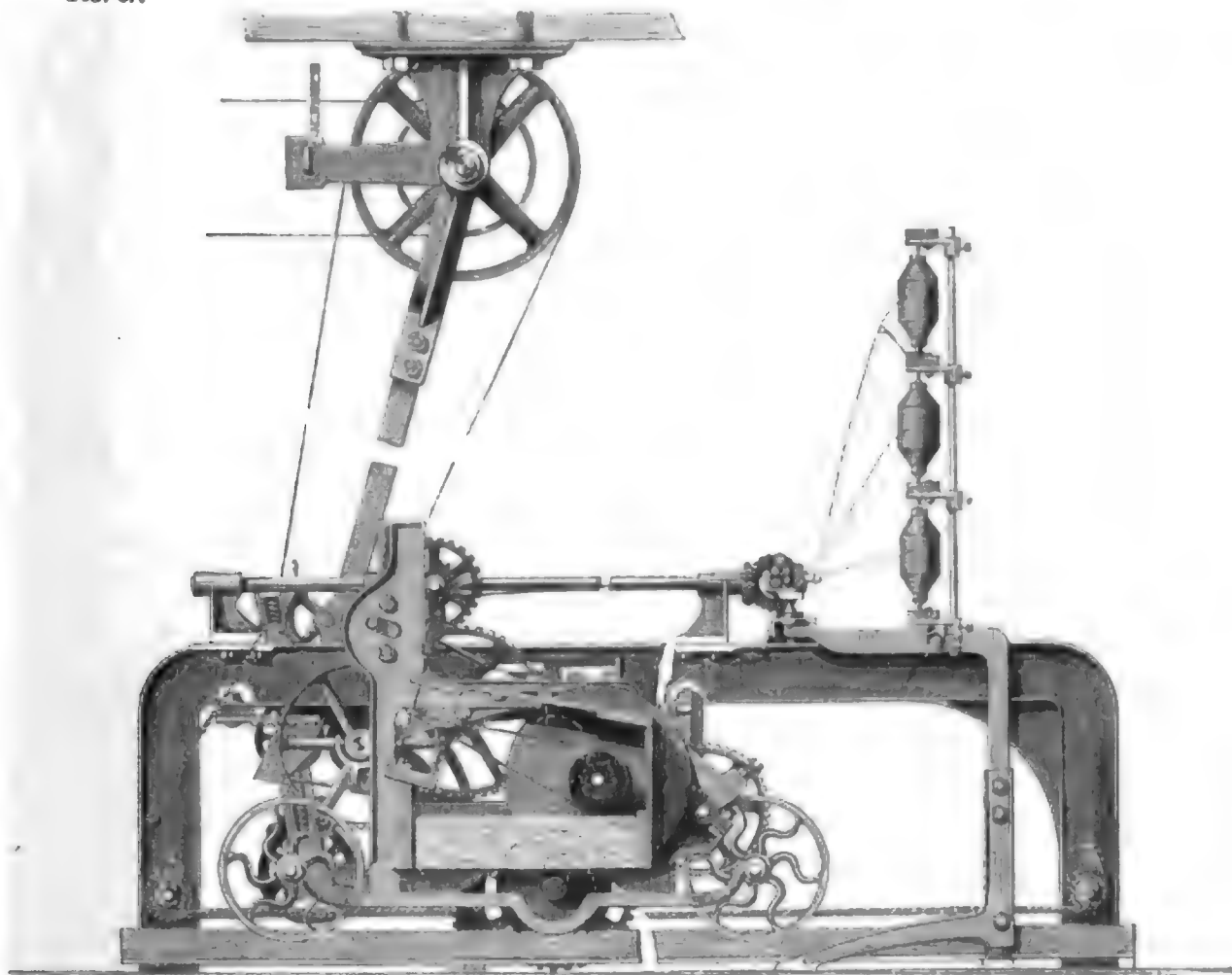
5. *Slubbing Frame*.—This frame is of the usual construction. To cheapen the labour of

attending to the frame, it is lowered four inches by reversing the bottom rail which carries the spindles, and is thus placed within the reach of smaller and younger girls. The cones for driving the differential motion are made larger than usual, thus reducing the liability to slip, and increasing the certainty of action. The driving-shaft is made of steel.

6. *Roving Frame*.—This machine is constructed similarly to the slubbing frame.

7. *Throstle Frame*.—The principal novelty in this machine is the duplicate tin cylinder for driving the spindles. Instead of one cylinder placed in the centre, with driving-bands right and left to the spindles, two cylinders are ranged side by side, and each cylinder drives the

FIG. 37.



HETHERINGTON & ROBERTSON'S SELF-ACTING MULE, by Messrs. John Hetherington & Sons.

spindles farthest from it; thus a longer band is obtained than with one cylinder, which reduces the liability to slip, and gives more nearly positive driving. The bands also work parallel to the driving-wharves on the spindles; they may be worked less tightly, and with less tear and wear, which is a considerable item of expense. This system is highly approved, and is extensively in use.

8. *Hetherington & Robertson's Self-acting Mule*.—This mule comprises some new and good

features. The motions are positive, the tin-roller shaft being driven direct from the intermediate shaft through the medium of a swinging-frame to direct the driving-belt. Thus the tin roller becomes the main driver when the carriage is coming out. It drives, first, the carriage, by means of a train of wheels, with a rack and pinion to run it out; secondly, the drawing-rollers, by a second train of wheels branching from the first train. Rim bands and other intermediate modes of driving are by this means dispensed with, perfect regularity of twist is

ensured, with a maximum production at a given velocity of spindle: the spindles being driven by cords from the tin roller. The motion of the cam-shaft is positive, and all its connections being on the carriage, the changes follow each other wherever the carriage may be on the stretch. When changing at the roller-beam, the change by which the inward run of the carriage is stopped, is effected by the motion of the carriage in the usual manner; but the cam-shaft is not permitted to complete the change until the faller has been raised. Thus the winder may stop the mule at the roller-beam, at any part of the carriage, by simply preventing the faller from rising. The outward and inward motion-clutches are changed by means of one spring, so that their functions cannot interfere with each other.

The backing-off movement is effected directly, without the intervention of bands, by means of a loose pulley, with toothed and friction gear, to reverse the tin roller and spindles. It is, therefore, done more promptly, and with less power than where the usual intermediate connections require to be reversed:—almost as quickly as, and much more easily than, stripping.

The motion of the quadrant and that of the carriage are positive to each other, as they are both geared with the same shaft, by two toothed pinions: one with the quadrant; the other, already referred to, with the rack on the head-stock. A constant degree of tension upon the yarns is thus insured on the starting of the carriage for every stretch, and the winding-on is definite. The drawing-rollers are positively connected with the carriage, by means of bevil gear on a slotted shaft: thus, they stop and start without shock, and simultaneously with the motion of the carriage.

The raising of the fallers at the beam is a critical operation, inasmuch as, if they be raised too soon, the yarn “snarls” or curls; if raised too late, the yarn “snicks” or breaks—a frequent source of annoyance. In Hetherington & Robertson’s mule this kind of uncertainty is removed, as the starting of the carriage is dependent on the rising of the faller, and thus the yarn may be kept at full tension by the faller-wire up till the moment the carriage begins to run out (fig. 37).

CHAPTER IV.

MACHINES EXHIBITED BY MESSRS. PLATT BROTHERS AND CO., OLDHAM.

Messrs. Platt Brothers & Co. exhibited, as in 1851, a complete series of cotton preparing and spinning machinery in motion.

1. *Platt & Richardson’s Gins*—*The Churka Gin*.—The improved churka gin is composed of two rollers, the lower of which is covered

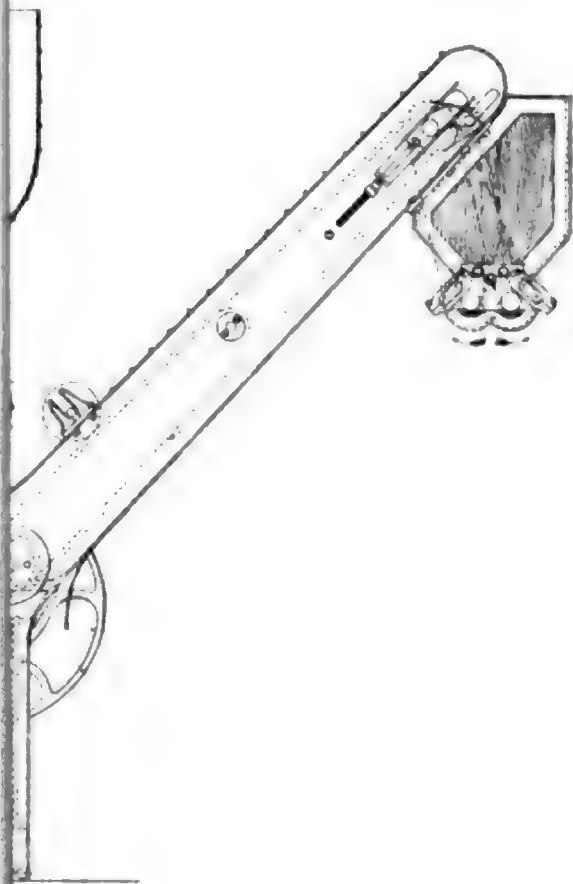
with hard wood, $1\frac{1}{2}$ inches diameter; the upper roller is of steel, $\frac{1}{2}$ inch diameter, with a finely fluted surface. The rollers work in contact, and are coupled by gearing, so that their circumferences travel at the same rate. The gin cleans all kinds of staple from hard seeds, one of the rollers being so small as to prevent the passage of the smallest seed. The fibre as it is separated is drawn through the rollers and delivered; the seeds drop through the grid in front of the rollers.

The improved churka gin exhibited, comprises some novelties, in which the rollers are held in contact by means of weighted levers, and are prevented from lapping the cotton. They are supplied with seed-cotton by a travelling lattice, which delivers it to a preliminary series of three spiked rollers, the first of which, revolving over the lattice at the same superficial speed, holds the cotton; the second travels much faster, and seizes the cotton; whilst the third, moving at a lower speed, prevents the second roller from carrying cotton in pieces on its surface. The cotton is stripped from the second roller and conducted to the churka rollers by means of a comb which vibrates on an axis at the back, and, seizing the cotton, which becomes loosened in the process, passes it to the churka rollers. The upper or steel roller is cleared by means of a steel knife fixed over it, and a leather-covered roller in contact with the lower or wooden roller: this roller is prevented from wrapping by a fan roller revolving under it. This gin is said to be capable of separating from hard seed about 100 lb. of clean cotton per day.

The Macarthy Gin.—The original Macarthy gin consists of a roller covered with leather, about five inches in diameter, having a number of small spiral grooves cut in its surface, and making about 110 revolutions per minute. Facing the roller, is placed a thin steel plate, bearing against it with a slight pressure, and the seed-cotton, placed on a wire grid, is pushed by hand against the face of the roller. The roller, by means of the spiral grooves, and the adhesiveness of the leather, seizes and draws the fibres under the steel plate, until the seeds come into contact with its edge, when a vibrating knife on the back of the plate ascends, and, passing the edge of the plate, pushes off the seed, and sets free the fibre, which travels with the roller, and is delivered over a rod in front of it upon the floor. This gin is still preferred when worked by native labour, as in Egypt and Turkey. The interspaces of the grid should be made to the size of the seed being cleaned: if too wide, the seeds drop through before they are completely cleaned. The gin, as made by the exhibitors, produces 30 lb. per hour of clean cotton, Smyrna or Indian; or 40 lb. per hour of Egyptian or American.

Platt & Richardson’s improvement in the Macarthy gin, for hand power, consists in working two knives from a double crank, which

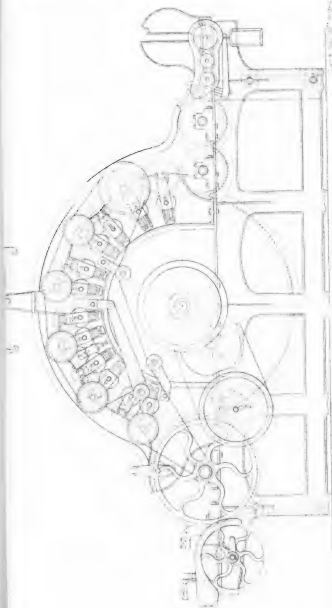
APPARATUS)



SINGLE CARDING ENGINE FOR COARSE NUMBERS

BY

MESSRS PLATT, BROTHERS & CO. OLDHAM



The rollers which strip the last dust-cylinder deliver the fleece to a set of four calender rollers placed over each other, so that the cotton in passing through them receives three compressions, which form the fleece into a kind of felt. Three of these calenders have their surfaces kept clean by bars of iron covered with flannel, which are pressed in contact with them. The cotton then passes over one of two large fluted rollers which revolves in the same direction, and under a smaller plain roller which is above the fluted roller, and receives its motion from it by contact through the fleece; this small roller also cleans the second calender roller by running against it in a contrary direction with a slight pressure: it also breaks the fleece when the lap is formed.

The fleece is now wound upon a light wooden bobbin placed in the channel between the two fluted rollers, when a third roller carried by racks at each end, on Knowles's patent, presses on and rises as the lap is wound. By the combined action of the three rollers a much harder lap is produced.

Finishing Scutcher.—The same in arrangement as the opening machine, with an additional provision for placing three of the laps made by the other machine upon it, which are unrolled together on the travelling lattice for the sake of the uniformity of fleece (fig. 39).

The process of double carding is exhibited—that is to say, the carding of the cotton in two carding-engines successively: the first a breaker, the second a finisher carding-engine, with the intermediate process of doubling. Double carding is generally employed for the finest quality of yarns. It is recommended for all numbers above fifties, when first-class yarns are to be produced; but for middling or ordinary yarns, below forties, single carding is generally practised.

4. Breaker Carding Engines.—Two breaker-cards are exhibited. One of them has, besides the taker-in, three self-stripping "dirt rollers" (Adahead's patent), with four rollers and four clearers; the other has two "dirt rollers," with five rollers and four clearers. The dirt-rollers work at a very low speed, and they aid in straightening the fibres as well as in intercepting the motes; they are stripped by a knife or comb, one to each roller. They are well applied in these machines, for making good work, and are worthy of being generally adopted. The cylinders are stripped by means of a brush, by which the wires are not so liable to be disturbed as when the hand-card is used (fig. 40, page 58).

5. Lap-doubler.—A machine called the "Derby-doubler" was exhibited, the object of which is to receive the slivers delivered from the breaker-card, to lay them side by side, and form a fleece, and coil them into a lap to supply the finisher-card. Two rows of tin cans, thirty-two in all, containing the slivers, are ranged on each side of the feeding-table. The slivers are passed through two pairs of calender rollers and deli-

vered on the table, from which they are received by another pair of calender rollers at the end of the table—thus undergoing a repeated compression; and they are wound on a wooden bobbin in the same manner as the fleece from the scutcher, forming a sliver-lap about 13 inches long. Three of these laps placed end to end form a complete lap for the finisher-card, which is 40 inches wide. The doubler is fitted with stop motions, to act when the lap-roller is filled, or when a sliver breaks or runs out. By this means missing slivers or "singles" are prevented, and the fleece is delivered in a uniform condition.

6. Finisher Card.—This machine continues the operation of combing and cleaning commenced by the breaker. Two such cards were exhibited, 40 inches wide on the wire, $40\frac{1}{2}$ inches diameter, with a 9-inch taker-in, 50 revolving flats on Leigh's system, and an 18-inch doffer. For the finer qualities of cotton of high counts, this engine is used at once as a breaker and finisher. For the finest qualities, it is used as a breaker card for cotton intended to be afterwards submitted to the combing machine.

The flats are of iron, placed in an endless train to form a lattice; they cover a portion of the main cylinder, and slide on a concentric path on each side of the frame, with a slow motion. The flats which are not engaged are turned back over plain slips on each side of the cylinder, to support them whilst their faces are being ground and sharpened by a traversing disc covered with emery. By a similar apparatus the main cylinder and the doffer are ground up. As the flats emerge out of contact with the cylinder, the impurities separated are stripped by a vibrating comb, and they fall into a receptacle. The finisher-card exhibited turns out less than 100 lb. of cotton per week, for hundreds yarn. But it would turn out 600 lb. per week for thirties yarn, after having been passed through the breaker-card (fig. 41, page 59).

Coarse Carding Engine.—40 inches on wire, $45\frac{1}{4}$ inches diameter of cylinder, patent feeder, taker-in 9 inches diameter, fancy roller 9 inches diameter, stripper over fancy roller 7 inches diameter, roller in connection with ditto 7 inches; five working rollers 6 inches diameter, five clearers $3\frac{1}{4}$ inches diameter, doffer 22 inches diameter, fly stripping comb, and coiling motion. (Plate VIII.)

The novel feature in this carding engine consists of a fancy roller, supported by suitable bearings on the framing, betwixt the taker-in and the main cylinder, which, revolving at a higher surface velocity than the cylinder, takes the cotton from the taker-in to the 7-inch stripper (brushing the cylinder in its course), which again delivers it to the main cylinder to complete the carding operation.

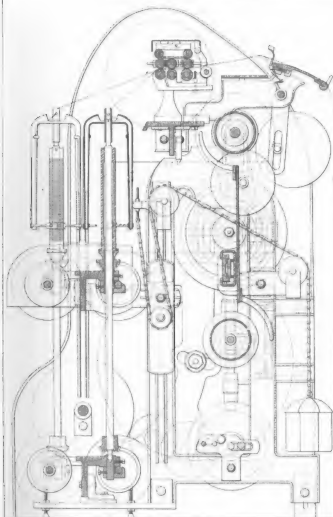
This engine will card about 1000 lb. per week for coarse numbers of yarn.

SLUBBING FRAME

BY

MESSRS PLATT, BROTHERS & CO. OLDHAM.

CROSS SECTION THROUGH THE CONE-DRUMS



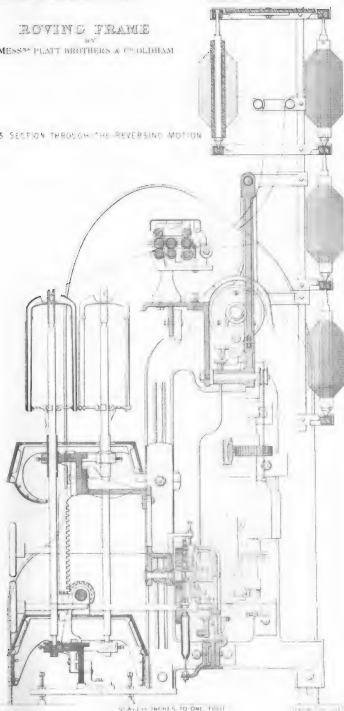
SCALE 12 INCHES TO ONE FOOT

Fig. 1. Slubbing Frame.

ROVING FRAME

BY
MESSRS PLATT BROTHERS & CO. OLDHAM

CROSS SECTION THROUGH THE REVERSING MOTION



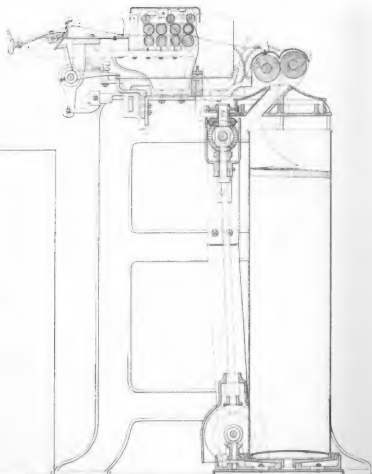
SCALE THREE INCHES TO ONE FOOT

DRAWING FRAME

BY

MESSRS PLATT, BROTHERS & CO. OLDHAM.

CROSS SECTION



SCALE $1\frac{1}{2}$ INCHES TO ONE FOOT

Day & Son Ltd. * to the Queen.

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the single length, it is more nearly uniform in tension, and may therefore be worked more slackly, and with less wear and tear. There is an improved arrangement for driving the cam-shaft by gearing instead of by friction, making the motion positive, and causing a more certain and noiseless action of the changes. The coping and faller-locking motions are simple; with double coping plates the coping rail may be taken out in any stage of the cop's progress without disturbing the other parts. Platt & Buckley's governor or cop-regulator is applied for adapting the winding-on motion to the formation of the cop, and is perfectly automatic (figs. 43, 44).

Messrs. Platt Brothers & Co. have, since the Exhibition, introduced another mule (Plate XII.), in which the bands of the drawing-out motion are fastened to the pulleys or scrolls on the drawing-out shaft, by which the starting of the carriage is ensured to take place as soon as the drawing-out motion is put in operation. The mechanism is so arranged that should any impediment be offered to the running out of the carriage it would disengage itself without injury; whilst it is positive in action. Secondly, the scroll-bands are directly connected to the carriage by elastic fastenings, which prevent undue strain on the bands by sudden action, and communicate to the carriage a soft delicate motion at starting. These bands are attached on each side of the square of the carriage; and the principal resistance to the taking-in movement,—namely, the turning of the spindles by the quadrant, or the winding-on chain,—being situated between them, there is not any tendency in the carriage to move endwise; and lateral friction between the flanges of the carriage-wheels and the rails is thus prevented. The scroll-shaft is so arranged that it may be taken out entire. Thirdly, a simple mechanism is applied for giving the change when the faller has locked, which prevents the carriage going in should it fail to be taken hold of by the holding-out catch when the drawing-out motion is disengaged. Fourthly, an arrangement of the backing-off and locking motions, so that the spindles are stopped simultaneously with the locking of the faller; which prevents the spindles from throwing the yarn off the “nose” of the cop, and admits of as good a nose at the finish as at any other part of the set. Fifthly, the connection of the holding-out catch with the lever for putting the taking-in catches in gear, so that the cam-shaft disengages the holding-out catch immediately before engaging the taking-in catch, thus preventing the confusion and breakage which might arise if two opposing catches were in gear at the same time. Sixthly, an arrangement to regulate the time for shifting the driving strap to the fast pulley, either simultaneously with the change of the cam-shaft for engaging the drawing-out motion, or before it takes place; and thus to lose no time in starting the spindles.

Seventhly, a similar contrivance, adjustable whilst the machine is in motion, for starting the rollers simultaneously with, or later than, the drawing-out motion.

The frame is generally constructed and adapted to form a casing for the working parts. The frame of the headstock is made in five castings—the top, the back, the tail end, and the two sides,—by which great stability is attained with more room for the working parts. The sides which connect the tail end to the back part are carried under the fallers, by which the piecer is enabled to see the threads from end to end of the machine. The adjustable parts are convenient for setting, and the changes are easily made when required for spinning various numbers of yarns. The diagonal rods for binding the carriage are placed through the middle of it, instead of underneath, so removing any tendency to buckle or lift the carriage off the middle slips or rails.

CHAPTER V.

MACHINES EXHIBITED BY MR. JOHN MASON,
ROCHDALE.

Mr. Mason exhibited an entire set of machines for preparing and spinning cotton.

1. *Scutcher and Lap-Machine*.—The cotton is fed by a travelling lattice, the beater has three blades, the grate or grid is carried forward from the beater to the “cages” or draught cylinders; the fleece is felted by calender rollers, and the lapping part has a self-acting motion to stop when the lap is completed.

2. *Carding Engine*.—This engine is mounted with six rollers and three clearers, and has, in addition, a “fancy” roller and a clearer equal in size to the taker-in, 8 inches diameter, and placed just over it. The fancy roller turns with the main cylinder, but with a higher circumferential velocity, and strips it of the cotton just received from the licker-in; the cotton is carded and returned by the clearer to the main cylinder, and passes on to the ordinary rollers and clearers.

Two small wrought-iron rollers cut with diamond points (Parkinson's system), $1\frac{1}{4}$ inches diameter, are also placed in conjunction with the licker-in, below it, to take out leaf or other dirt, and partially to comb the cotton before it is delivered to the main cylinder; and no doubt they operate in this way. But it may be remarked that grids have, within the last few years, been very generally applied to encircle the licker-in underneath, to keep the fly, whilst passing out the dirt; and it may probably prove inconvenient to apply the rollers in this manner.

The side frame-plates are made with concentric "bends," to afford a convenient and accurate base to work from in adjusting the rollers and clearers, which will prove serviceable. There is a small eccentric apparatus fixed in the bends for tightening the roller chain.

3. *Drawing Frame*.—This frame is made with three heads, and four deliveries in each head. It is fitted with back and front stop-motions.

4. *Slubbing Frame*.—This is a good and well-known machine. It has an extended bearing for the spindle; the collar, which is fixed to the lifting rail, is continued through the pinion

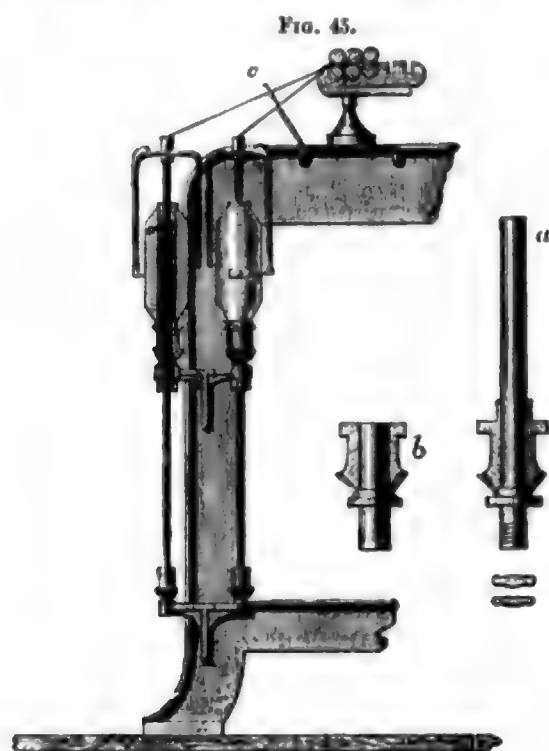


FIG. 45.
COLLAR FOR SPINDLES IN SLUBBING FRAME, by Mr. John Mason, Rochdale. *a*, extended bearing; *b*, ordinary bearing; *c*, separating plate.

wheel, inside the bobbin, and nearly to the top. This gives greater steadiness and admits of greater speed and greater production (fig. 45).

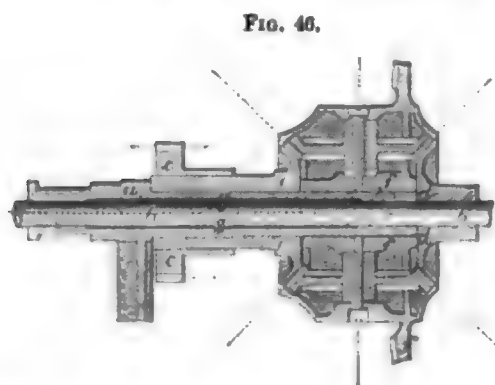


FIG. 46.
DIFFERENTIAL OR JACK MOTION, with Long Boss; by Mr. John Mason. *a*, extended boss, carrying the wheels *c*, *e*, *f*.

Separating plates of sheet iron are fixed along the frame between the drawing rollers and the spindles, for preventing the ends of the rovings

when broken from being entangled with others and causing waste; the rovings are passed through slits in the plates.

The novelty consists in a lengthened boss applied to the differential or jack motion extending through the jack-box, — thus separating the rubbing surfaces of the box and shaft, which turn in opposite directions, causing them to work more steadily and with greater durability (fig. 46).

5. *Roving Frame*. — This machine is constructed similarly to the slubbing frame.

6. *Throstle*. — A well-made machine of ordinary construction.

CHAPTER VI.

MACHINES EXHIBITED BY MESSRS. WILLIAM HIGGINS AND SONS, MANCHESTER.

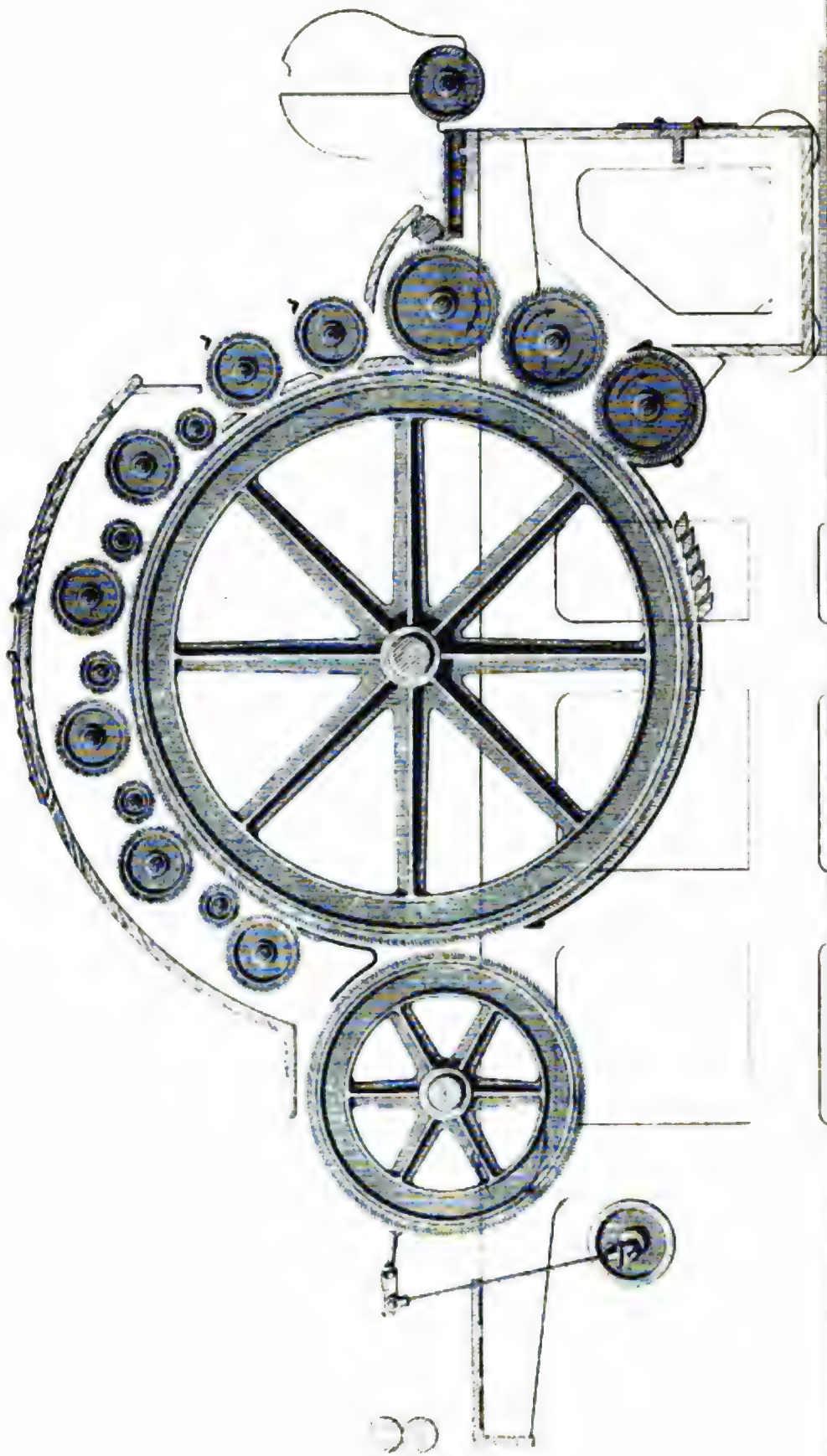
Messrs. Higgins & Sons exhibit some suggestive appliances for improving the performance of carding engines and spinning frames.

1. *Carding Engines*. — Three varieties of carding engines were exhibited, showing the application of the principle of automatic cylinder-stripping, originally invented and patented in the United States, and brought into notice in England by Messrs. Higgins. Two additional rollers are placed beneath the lick-in roller; clothed in the same manner and revolving in the same direction, near to each other and to the main cylinder; the bottom roller being called the stripper, the other the intermediate. The cotton is delivered by the feed-rollers to the lick-in as usual; but before it reaches the main cylinder it is brought into contact with, and is carded by, the intermediate roller, which allows only the carded portions of cotton to pass to the cylinder, the larger masses being taken hold of by the intermediate roller, and carried forward until they are brought into contact with the bottom roller, which still further cards and separates the fibres of cotton, allowing an additional portion to be delivered to the cylinder. The remainder is taken on by the bottom roller, and likewise deposited on the cylinder. Thus, instead of the cotton being delivered in flaky masses upon the cylinder by the lick-in, as in the ordinary mode, it is first well opened and carded, separated from dirt and seeds at the most convenient point, and then distributed lightly and evenly over the surface of the main cylinder at three separate points.

But the bottom roller or stripper also, as its name indicates, strips the main cylinder. This is ingeniously effected by working the stripper at a varying surface-velocity, alternately faster and

AUTOMATIC CARDING ENGINE
BY
MESSRS WILLIAM HIGGINS & SONS, MANCHESTER.

LONGITUDINAL SECTION



SCALE 8 INCH TO ONE FOOT

Drawn by J. H. L. & Co. to the Queen.

slower than that of the cylinder: so that, in the first place over-running the cylinder, it strips it and carries forward the cotton to the intermediate, which re-cards it and delivers a portion to the cylinder; in the second place, the cylinder over-running the stripper strips it of the cotton left on its surface. These alternations of speed take place fifteen times per minute, and it is stated that, in virtue of this mutual stripping action, the cylinder does not require to be stripped by hand, and needs only to be stopped for grinding.

The peculiar principle of this card is no doubt a useful one. The main cylinder, the principal member, should be well protected, as the more carefully it is dealt with, the longer it lasts in good condition, and the better the quantity and quality of the work done. No doubt, the quantity of work done is increased by the addition of the two rollers, a higher speed of cylinder being thereby attainable. It may, nevertheless, be suggested that, as the stripper merely acts on the points of the wires of the main cylinder, the wires are likely to be gradually filled up with dirt: a bristle-brush forcibly applied to the clothing, and revolving at a good speed, as in Rivett's machine, would clean it out to the roots of the wires; and, on this assumption, the stripper might do better if retained as a worker at a uniform speed, a bristle stripping roller being applied in addition. It is stated, however, that in a mill which was filled with Messrs. Higgins's cards, where fifteen persons were required for stripping and grinding, three are now found sufficient.

The first card has a 45-inch cylinder, with six rollers and six clearers, a 9-inch lick-in, the stripper and intermediate roller 8 inches diameter, and a 22-inch doffer. The main cylinder makes 160 revolutions per minute, or a superficial velocity of 1,884 feet per minute, which, as compared with the ordinary speed of a 40-inch cylinder,—135 revolutions per minute, or 1,418 feet per minute superficial velocity,—is one-third greater. This card is suitable for single-carding for low and medium numbers; the production is stated to be 1,200 lb. per week for sixteens to twenty-fours. The variation of speed of the stripper is effected by means of a pair of conical drums, on which the belt is traversed from end to end by a cam-motion.

The second card (Plate XIII.) contains five working rollers and five clearers, and two self-acting dirt rollers. This card is well adapted for medium numbers, and will produce about 1,000 lb. per week of good carding for thirties, or 900 lb. for forties.

The third card has four rollers and four clearers, with a revolving sheet of 22 flats, Evan Leigh's patent. This card is generally adopted for fine spinning, and yields a production of 800 lb. per week for fifties, or 600 lb. per week for eighties.

For the high velocities of their cards, Messrs.

Higgins employ a doffing-comb of very light proportions, which works rapidly. The ordinary comb-stock is dispensed with, and a comb resembling a band-saw is hung in tension from two double arms on a central shaft, with a counter tension-rod at the other ends of the arms; any required degree of tension may be thrown on the comb by means of tightening nuts screwed on the tension-rod. The comb is vibrated by light iron rods from the cranks. The whole of the reciprocating parts are thus reduced to very light proportions, and are nearly self-balanced.

2. Slubbing Frame.—The chief novelties consist in the arrangements for supporting and driving the spindles, which are good, though somewhat luxurious. The upper parts of the spindles are effectually supported by an extended stationary tubular bearing or bolster, extending from the lower spindle-rail to the bottom of the flyer. This bearing is suspended on double pivot-joints at right angles to each other, suggestive of and, in effect, universal joints; one of them attached to the spindle-rail and the other to the coping-rail. By means of these joints, compensation is afforded for irregularities in the action of the coping-rail, or in the levels or fittings of the machine, and the bush slides freely on the tubular bearing. The spindle, revolving freely within this tube, is entirely unaffected by the traverse of the coping rail, which occasionally binds it in the common frame. Thus, Messrs. Higgins possess the same advantage as Mr. Mason, in an increase of steadiness with an extended bearing, combined with freedom for the spindle, to suit itself to irregularities. The pinions for driving the spindles are connected, without the ordinary set-screw, by squaring the lower ends of the spindles, which fit easily into square holes in the pinions. The pinion is supported in an independent bearing, so that the spindle and flyer can be withdrawn from the frame and replaced, without affecting the pinion; which facilitates the cleaning and oiling of the frame, though, as a set-off, there is the extra friction of the extra bearing. By these means, the spindles may be run with steadiness at velocities considerably higher than are usual. They ran at 1000 revolutions per minute at the Exhibition, making bobbins 10 inches long by 5 inches diameter. The ordinary speed of slubbing spindles is 500.

3. Roving Frames.—Two roving frames are exhibited, with the same appliances to the spindles and flyers as have been described for the slubbing frame. Preston's centrifugal presser, also, is applied to the flyers, suspended on an incline, which induces the presser to remain in contact with the bobbin, preventing it from flying off and breaking the roving when the frame is stopped. The flyers are made with but one tube and presser, for the reason that in practice the

attendants use only one side of the flyer; and a second tube, if unused, is liable to be filled up. One of the roving frames made bobbins 7 inches long by $3\frac{1}{2}$ inches diameter, at 1,650 revolutions; and the other, the fine roving frame, produced bobbins $4\frac{1}{2}$ by $2\frac{1}{4}$ inches, spinning fifties at 2,000 revolutions per minute. The speed of the ordinary roving frame is about 900 revolutions. (Plate XIV.)

4. *Throstle Frame*.—In this frame there are means of regulating the drag of the bobbin, by a cord which is held taut, stretched by a weight, across the bobbin rail against and in a groove in the bottom of each bobbin. The friction or drag is regulated by shifting or lapping the cord more or less in the groove. The principle is correct, but it has been found that the junior attendants meddle with and shift the cords, and make an irregular drag, resulting in bad spinning and waste. Though not much used in England, this drag-motion is extensively applied on the Continent.

CHAPTER VII.

MACHINERY EXHIBITED BY MESSRS. DOBSON AND BARLOW, BOLTON.

Messrs. Dobson & Barlow exhibited a complete system of machines, arranged and adapted for preparing and spinning cotton yarn of fine numbers.

1. *Cotton Opener*.—Devised for opening and cleaning both long and short staple cotton. The machine differs in construction from the other openers exhibited, inasmuch as it has two cylinders 30 inches diameter, set one over the other, running about $\frac{1}{2}$ inch apart. The cylinders have each ten wrought-iron blades or knives, armed with twenty-eight steel-faced teeth, placed zig-zag on one side of each blade. The feed rollers are made with a series of annular grooves and ribs fitting each other; and the tops of the ribs are fluted to grip the cotton, and yet to let seeds or shells pass through without crushing them. For cleaning dirty cotton, as Egyptian, or Surat, the two cylinder-beaters revolve in opposite directions, and they both operate on the cotton. The cover of the upper cylinder is fitted with ribs, against which the cotton is projected by the cylinder; the lower cylinder, running in the opposite direction, drives it over a grid as usual, when it is taken off by a fan-draught. For cotton requiring less opening or cleaning, as Sea Island or Orleans, the cylinders revolve in the same direction. The change in direction is effected by crossing the belt for the upper cylinder and diverting the current by a valve. This machine, it is stated, opens 60,000 lb. of

cotton per week. It embodies an excellent principle of compound or combined action. (Plate XV.)

2. *Single Scutcher*.—This machine has lapping parts attached, with consolidators, fan, and feeding lattice for doubling four laps.

3. *Breaker Carding Engine*.—This machine has two working rollers and twelve flats, which are self-stripping, on Wellman's system. The cotton is, in the first place, opened and cleaned by the working rollers before it reaches the flats. The process of stripping the flats consists in raising them out of their beds without turning them over, and drawing a wire brush across the face of the flat, which removes the fly and dust. Each flat is pressed gently down upon the stripper during the operation; alternate flats being lifted in succession. The stripping mechanism is sustained by and vibrates on the main shaft, over the range of the flats; and the movements are effected by means of an irregular groove guide or cam motion, with suitable connections for lifting and lowering the flats, and passing and withdrawing the brush. The speed of the stripper is adjustable to strip from one to five flats per minute. The flats are supported by adjusting screws, and may be taken out at any time. The action of the hand in stripping is imitated in this machine; but with greater regularity, and producing better work. (Plate XVI.)

4. *Lap Machine*.—This machine is on Ashworth's system, to make laps, for the finisher carding engine, of the slivers from the breaker card. It is for precisely the same purpose as the Derby doubler exhibited by Messrs. Platt Brothers & Co. The plates at the end of the lap revolve with it, and prevent the edges from being felted together, thereby preventing waste.

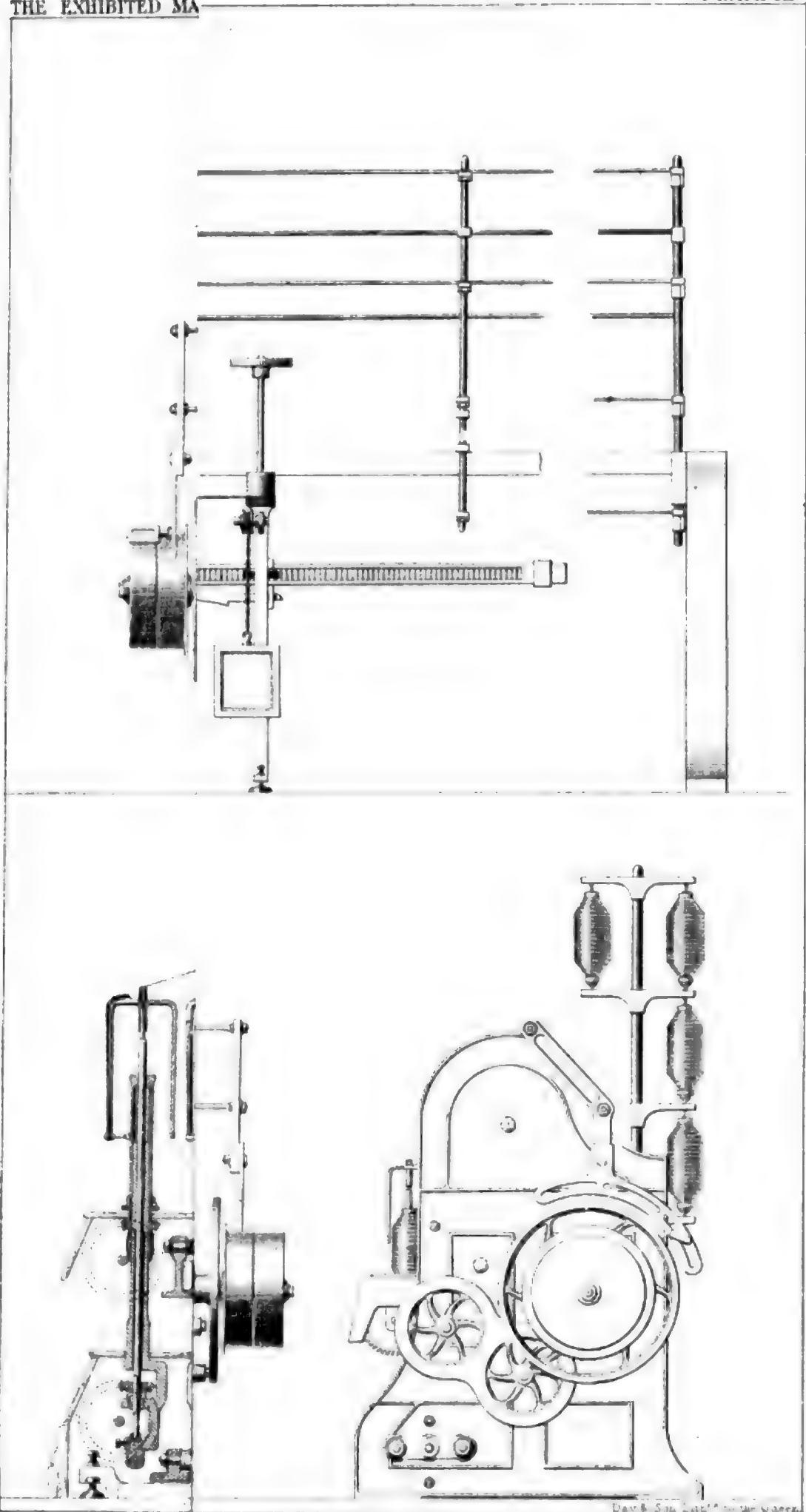
5. *Finisher Carding Engine*.—This engine is mounted entirely with flats, stripped automatically on Wellman's system, like the breaker card. The cylinders of both cards are stripped by hand-comb, or with a brush-stripper, which prevents the card-clothing from being injured.

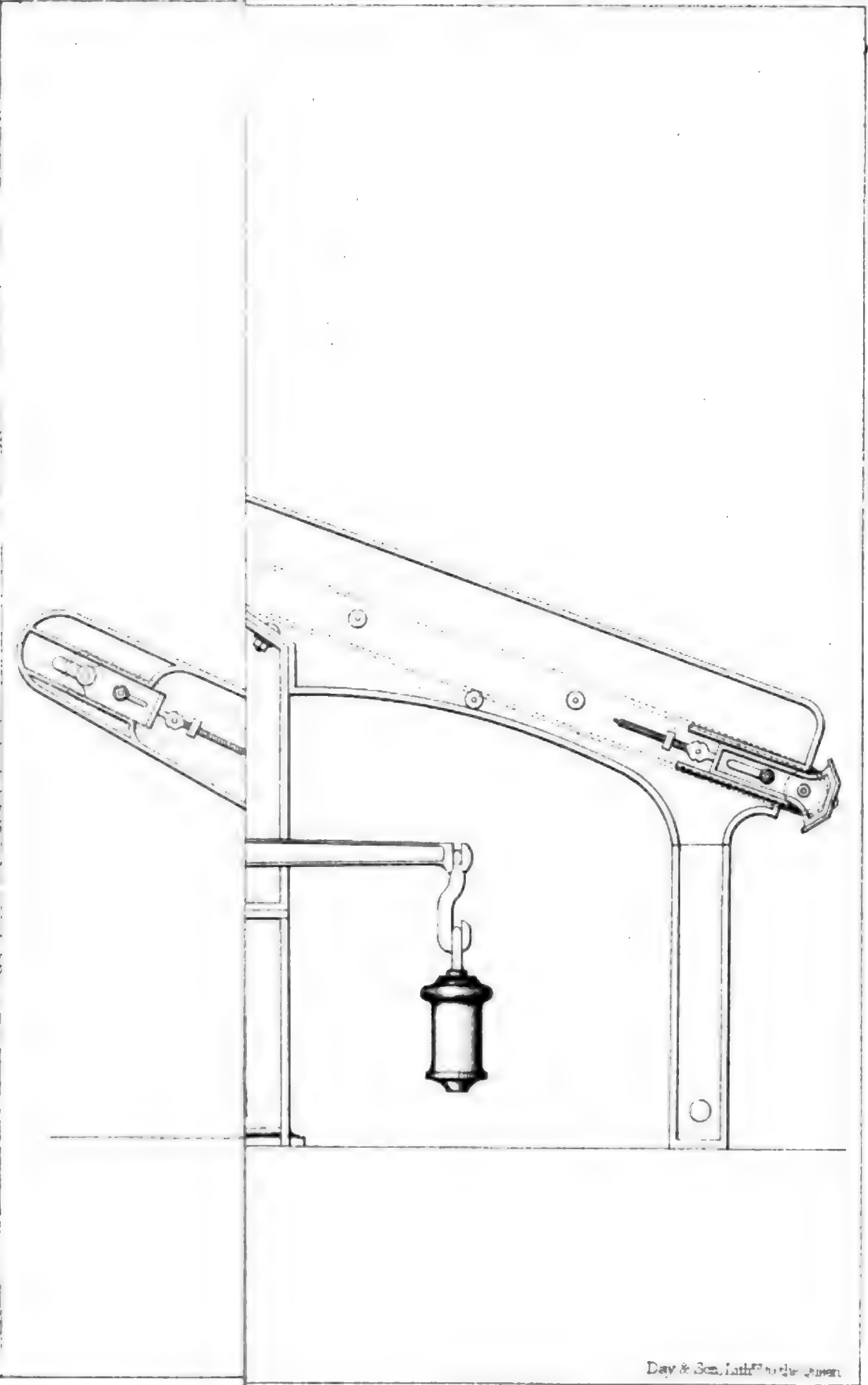
6. *Grinding Machine*.—For grinding two rollers and two flats at a time, with adjusting screws for setting each independently.

7. *Drawing Frame*.—Of three heads and three deliveries, with front and back stopping motions; and four lines of rollers, coilers, and cam motions.

8. *Slubbing Frame*.—Of 44 spindles, bobbin 10 by 5 inches; with centrifugal pressers. The gearing is carefully cased up.

9. *Intermediate Frame*.—Of 54 spindles, bobbin 8 by 4 inches; with centrifugal pressers.



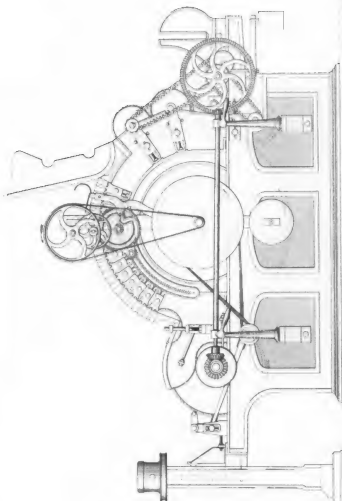


Day & Son, Litho to the Patent

COMPOUND PATENT CARDING ENGINE

BY

MESSES DOBSON & BARLOW, BOLTON.



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10. *Roving Frame*.—Of 70 spindles, bobbin 7 by $3\frac{1}{2}$ inches; with centrifugal pressers.

11. *Jack Frame*.—Of 88 spindles, soft bobbin 5 by $2\frac{1}{2}$ inches. This frame has produced rovings of the fineness of 125 hanks to the pound.

12. *Self-acting Mule*.—In this mule double roving is spun; that is to say, two rovings are drawn into one thread. Or, single roving may be used for coarse numbers.

This mule, compared with others, has two additional motions, necessary for spinning fine yarns,—namely, the second stretching motion, and the extra twisting motion. The object of this stretching motion is to stretch or draw out all unevenness or curls in the thread that may arise through inexact raising of the fallers at the beam, or inequality between the speed of delivery from the drawing rollers and the speed of the carriage in running out, or from any other cause. When the carriage arrives at about one and a half inches from the end of its traverse, the rollers are stopped whilst the carriage, by means of a differential motion, slowly completes its traverse. But the length of stretch may be varied from one quarter to six inches, without stopping the machine. The spindles continue to revolve and to give extra twist to the yarn, for about fifteen seconds, making 6,200 revolutions per minute. These motions are effected by means of levers and weights, without friction or cam-shaft. The additional functions of stretching and twisting involve additional mechanism about the head-stock; but these motions may be used or not at discretion. No change of gear is required when the rollers stop, thus ensuring the steadiness of the carriage, and freedom from strain on the yarn. The changing motions are positive. The winding-on quadrant, which is self-acting, ensures the yarn being properly wound on at the nose of the cop. The mule was spinning one-hundreds at the Exhibition. It is adapted for spinning the coarsest as well as the finest numbers of yarns, either twist or weft, from short or long staple cotton. (Plate XVII.)

CHAPTER VIII.

FOREIGN COTTON MACHINERY.

The contributions from foreign countries were scanty. Messrs. A. Rycx & Son, of Ghent, Brussels, exhibited a carding engine, of which the peculiar feature consisted in causing the clearers to revolve in the contrary direction to the rollers, with the object of causing the dirt to be collected on the rollers.

M. J. Beugger, of Winterthur, Switzerland, exhibited a roving-frame, so arranged as to form

the rovings on a rod in the can, instead of on a bobbin.

Mr. Horace L. Emery, of Albany, New York, U.S., exhibited an improved saw-gin, designed to remedy the defects of the Whitney gin, to which reference has already been made in the notice of the gin in the preliminary chapter. The advantage claimed for Mr. Emery's gin is, that it may readily be adapted to the various conditions of the cotton treated—long or short staple—and that a larger quantity can be better cleaned than by other gins, in the same time, with half the power. The chief novelty is a light wood shaft, thickly studded with smooth-pointed wood pins, placed in the chamber or hopper which supplies the cotton to the saws, and suspended in bearings at the sides, with sufficient orbital freedom to admit of the shaft always occupying the centre of the cotton roll which envelopes it. The roll is so sustained by it as to revolve freely, and to be presented uniformly to the action of the saws without bearing or pressing on them or on the bars between them,—thus preventing, it is stated, “any choking, clogging, bridging, napping, abrasion, or injury to the staple.” For short staple, the saws, 9 inches diameter, are placed about $\frac{7}{8}$ inch apart, and project about $\frac{1}{2}$ inch through the grate; for long staple, each alternate saw is removed, and replaced by a plain steel disc, and the speed is reduced. The brush cylinder is made with a sheet-iron covering, with concave plate-heads, and with stationary flanges fixed to the inside of the gin around the brush-heads, to prevent firing. The brush revolves faster than the saws, and clears them of the staple, exciting at the same time a strong draught. A “condenser,” consisting of a large revolving wire-gauze cylinder, is placed horizontally across the discharging side of the gin, through which the draught from the brush passes to the inside, and out at the ends, carrying with it the loose dust and sand. The cotton is arrested upon the cylinder, and passes out in a thick sheet or fleece through a pair of delivery rollers (fig. 47).

A 35-saw short-staple gin makes about 300 revolutions per minute, and is said to clean from 40 lb. to 50 lb. of cotton per saw per day, which is nearly fifty per cent. more than is done with the Whitney gin in common use. For Sea Island cotton, to spin hundreds, the speed is from 90 to 100 revolutions per minute, being stated to turn out about 600 lb. per day. The total production for 35 saws, at 50 lb. per saw, would be 1,700 lb. of short staple cotton per day, which is considerably greater than the reported production of Messrs. Platt's 40-inch Macarthy gin. It would be of importance to ascertain the relative values of the two staples so produced, when spun. The improved saw-gin worked upon various qualities of cotton at the Exhibition, and turned out the cotton in a very clean condition, combining the functions of an opener with the special function of ginning.

CHAPTER IX.

CONCLUDING REMARKS ON THE MACHINERY FOR PREPARING AND SPINNING COTTON.

The progress made since 1851 in cotton preparing and spinning machinery, may be summed up in four words:—improved workmanship, better and more extended automatic action, higher speeds with increased productive power, and better quality of production. In the materials and workmanship employed in the manufacture of cotton-spinning machinery, in their extensive and thorough organization of labour, and in the selection and unsparing employment of tools wherever they could be advantageously applied, Messrs. Platt Brothers & Co., formerly, in 1851, Hibbert, Platt, & Sons, have for many years taken the lead of their competitors; but the Exhibition of 1862 has shown that other constructors are following them up pretty closely. They have, nevertheless, been, and continue to be, at the head of their business as machinists; and the knowledge of the principles of construction, beyond the technical forms of stereotyped practice, manifested in their works, proves that they are not merely machinists, but engineers also.

It is satisfactory to find the principle of the roller-gin so well matured and worked out by Messrs. Platt Brothers & Co., as they have done in their improved Macarthy gin. It is impossible to conceive a more harmless method of dealing with the seed-cotton: the process of ginning being, by a dead pull on the staple, which is gripped between two rollers, to hold it whilst the seed is pushed or drawn off. There can be no doubt, again, that Mr. Emery has made a substantial improvement on the saw-gin, and there is much to be said for a continuous circular movement, in preference to a reciprocating movement, if other conditions be alike. The two principles, as respectively embodied, will, no doubt, be brought to the test of practice.

In the opening and the scutching machines of Messrs. Platt Brothers & Co., note the excellent proportions of the toothed cylinders, which are provided with numerous teeth, only $\frac{3}{16}$ inch thick. They are much more effective in opening and shaking the cotton, and separating the sand and other solid matter from it, than when the teeth are thicker and fewer in number,—as, for example, in Messrs. Walker & Hacking's opener, in which there are only six rows of teeth $\frac{1}{8}$ inch thick. With the thinner and more frequent teeth, the fibres are allowed to slip aside between the teeth more readily, until they are at last taken off. The broader teeth act more like the knives of the beater, which would not be appropriate for the first operation of opening dense masses of cotton, but would be more likely to break or twist the fibres, or cause them to "twitter." Messrs. Platt Brothers & Co. prefer drawing their supply of air entirely through the grids, as the current prevents the cotton passing

down under the stroke of the beaters: in this particular they differ in opinion from Messrs. Hetherington & Sons, who divide the draught so as to allow the dirt to fall more freely through the grids. Note, further, in this connection, the use of wire, by Messrs. Platt, for the draught-cylinders, instead of the usual perforated plate. A round hole makes an eddy, which twists the cotton; the wires make continuous slits, which cause the draught to act uniformly on the cotton. Careful, sometimes delicate, adjustment of the partitions is required to get a broad current of uniform power to avoid eddies amongst the floating cotton, and to draw it uniformly over the surfaces of the cylinders, and make a good lap. Messrs. Dobson & Barlow exhibited an arrangement of combined opener, with two cylinders, which were compounds of beater-blades and teeth. By their vertical arrangement, one over the other, the cotton may be passed through one or both cylinders, as required; and the added force of a blow from the second beater upon the cotton flakes, approaching it in the opposite direction with the velocity of the first beater, should tell with great effect in opening the flakes and dispersing the dirt.

Lord's feed-regulator is a good motion, and has been frequently applied. It is a delicate apparatus, and should not be implicitly trusted. It is easy to get out of order: the strap may slacken and slip, or it may be caused to slip by oil getting upon the drums, and the speed of delivery will be injuriously affected by such an occurrence. The weighing and uniform spreading of the cotton upon the travelling creeper of the breaker machines should therefore be continued as usual; and, in conjunction with this, Lord's feeder acts as a serviceable adjunct. One hour's bad work in the "blowing room" will give ten hours' bad work all through the mill, and every means of ensuring uniformity of lap should be employed in that department. Since the expiration of Lord's patent, the apparatus has been considerably improved by other makers.

The substitution of iron for wood in the construction of carding cylinders and rollers, has materially enhanced their efficiency and durability; and there is nothing, probably, in the whole range of cotton machinery which demands a nearer approach to absolute exactness in form and fitting, as the component parts of a carding engine. The application of continuous self-stripping appliances to the cards is a notable novelty. In Wellman's self-acting flat-stripper, exhibited by Messrs. Dobson & Barlow, the operation is performed by a single stroke of a wire brush across the face of the flat; and it contrasts with the revolving brush-stripper of Messrs. Hetherington, in which, with the revolving motion, a greater extent of stripping surface may be brought to bear upon the flat than in Wellman's; and there is, in addition,

a self-acting stripper, to keep the stripping-roller in good condition. Messrs. Hetherington's flat stripping motion was complicated, but it worked satisfactorily; and, in combination with Rivett's self-acting cylinder-stripper, also exhibited by them, it would make an excellent machine—wanting, however, the self-grinding appliance which Messrs. Platt Brothers & Co., apply to the revolving flats of their cards. This arrangement of self-acting flats works very well when truly set; and it is a work requiring great care and most exact workmanship, that the lattice may move in a truly circular and concentric path, and at the exact distance from the surface of the main cylinder. Such an arrangement would have been impossible but for the timely substitution of iron for wood in the construction of main cylinders. It is a most important matter to have all the working parts of a carding engine very nicely fitted, whether with flats or rollers, and that they should work steadily on firm bearings. In a revolving train of flats, the pivots are movable, and the joints must be loose enough to work freely. Nevertheless, with first-rate workmanship the moving parts are as steady as the fixed parts when set.

The design of the stripping rollers exhibited by Messrs. Higgins & Sons, and by Messrs. Hetherington & Sons, whereby the stripper, having a variable velocity, becomes alternately a stripper and a worker of the main cylinder, is an ingenious and serviceable design; and, apart from the question of quality, it no doubt affords a means of effecting an increase in quantity of production.

A variety of doffing-combs were exhibited, but the one most generally adopted is the fly-comb, which consists of a vibrating shaft having a number of projecting arms, to the ends of which the ordinary doffing-comb plates are attached. The comb-stock is thus dispensed with. By its vibrations, the comb-stock fans the loose fibres from the web, and creates a deposit of waste.

The combing machine exhibited by Messrs. Hetherington & Sons is a plain application of common-sense. The function of the machine is

simply to select the longest fibres from the staple, and to discharge all the shorter fibres. The picked fibres are to be selected of one length,—the greatest length;—a problem plainly insoluble by the agency of the carding engine alone, in which all that can be done is that, whilst the longer fibres in general remain in the cylinder, the shorter fibres are, in general, taken out in the rollers and the flats. But, when a complete separation is demanded, the comb is applied, to search out the shorter fibres one by one, whilst the longer fibres are held by the nippers and the rollers,—reverting, in fact, to the principle of the roller-gin. The alternating motion of the machine, however, retards its production; and what is yet to be done is to apply a continuous circular motion to the process of combing.

The top rollers invented by Mr. Evan Leigh have proved their usefulness by their having been generally applied in drawing and other frames. The extended bearings and universal-jointed supports for slubbing and other spindles brought out by Messrs. Higgins & Sons, are likely to prove useful in facilitating the adoption of increased speeds of spindles, particularly for short or inferior staples; though it is evident that the universal joint is a necessity attending the long bearing, inasmuch as a long bearing is more liable to bind than a short one. It remains to be considered whether—having secured an unyielding floor and ensured correct fitting, such as should be expected from competent machinists, the ordinary spindle, with long bearings, will not work as well without the universal joint.

The self-acting mules displayed much ingenious contrivance and mechanical refinement, suited to the complex operations required of them. In and about the headstock of a self-acting mule, there is probably concentrated as much really meritorious design, the work of first-rate mechanics, as in any other machine in existence. It must be absolutely automatic, independently of the matter operated upon, which is too delicate to offer either assistance or resistance; and its changes must for the same reason be timed with absolute exactness.

SECTION II.

MACHINERY FOR THE PREPARATION AND SPINNING OF WOOL.

CHAPTER I.

INTRODUCTION.

In the elaborate and valuable report on woollen goods by the Jury on Mixed Fabrics, the reporter, Mr. H. S. Way, dwells strongly upon the extraordinary progress made since 1851 in the woollen manufacture, amongst the principal features of which he mentions the increased supply and better quality of foreign and colonial wool, and, in low goods, the extensive use of old or second-hand materials mixed with new, besides the improvement in machinery and mechanical contrivances of every kind. Vast quantities of good-looking and highly serviceable woollen articles, he says, are now produced at very low prices, owing, in connection with the improvements in machinery, to the introduction of cotton warps, and to the clever and ingenious use of old or second-hand wools, known as shoddy, mongrel, and "extract," which are mixed with certain proportions of new wool to give the required strength and durability.

In 1851, the total importation of wool from all sources was 317,881 bales; and in 1861 it amounted to 520,743 bales, most of which was sent from the colonies, including, besides wool, other valuable raw materials,—as alpaca, mohair, and cashmere. The woollen goods produced for many years prior to 1850 were hard, stubborn, and inelastic, owing partly to the properties of the wool, and partly to the prevailing fashion of wearing high-dressed glossy cloths. But the fashion changed with the introduction of Australian wool, with its short silky staple, which was better adapted for making soft, elastic, and pliable fabrics; hence the prevalence of such articles, which have materially increased the comfort of the wearer during the last ten years.

As cotton also enters largely into the composition of mixed woollen fabrics, Mr. Way takes the opportunity of hinting that there was just as great an outcry and prejudice against colonial wool thirty-five years ago as there is against colonial cotton now; and as the former has distanced all competitors, he hopes that in the course of time the latter also will be as much appreciated.

Shoddy!—The very name at one time was sufficient to excite prejudice and disgust. But the useful properties of shoddy have long since been recognized, and the industry of whole districts depends upon it. Shoddy is of three kinds:—1, shoddy, made from soft woollen rags, as flannels, blankets, stockings, and carpets; 2, mungo, made from hard and fine woollen rags,

new cloth cuttings, and such materials; 3, extract wool, that is, wool extracted from mixed cotton and woollen rags by a chemical process, in which the cotton is consumed, and the wool is left intact. Of the three sorts, shoddy and mungo are held in the highest estimation, possessing better felting properties than extract. The conversion of woollen rags into shoddy is effected by a simple process in a machine, of which the principal part is the "swift," revolving within a cylinder. The swift contains ten to twelve thousand iron teeth or spikes, fixed in diagonal rows upon it, and is driven at the rate of six to nine hundred revolutions per minute, tearing or grinding the rags into shoddy. A machine of this description was exhibited by Mr. Rhodes, of Morley, near Leeds. Shoddy is mixed with new wool for manufacturing, in the teasing and carding processes; and the practised eye and touch alone can detect its presence in woollen goods. It has recently been calculated that the annual production of rag-wool or shoddy in the United Kingdom amounts to forty million pounds; and that twenty-five million pounds are imported, making a total of 65,000,000 lb. annually consumed in this country in the manufacture of woollen goods,—a quantity equal to the net produce of about 250,000 to 260,000 bales of raw wool, or nearly one-half the quantity imported in 1861. Shoddy, with very few exceptions, enters into the composition of all classes of medium and low woollens, and is second only in value and importance to wool itself; but it should be judiciously used, as there must be a sufficient admixture of new wool to give the requisite strength to the fabric.

In a notice of the improvements and economies recently effected by the application of machinery in the woollen manufacture, Mr. Way refers to the method generally in use for washing and scouring wool, in which the wool is immersed in a pan or vat containing hot alkaline lye, where it is worked about by men with wooden poles until the grease and other matters are extracted; then taken out, passed through clean water, rinsed, and dried. By this system two men and a boy could scour 500 lb. of wool in a day, at a cost of, say, 10s. for 500 lb. But by the use of the scouring and drying machine, the work is now better done with one man and a boy at a cost of 6s. for scouring 1,200 lb.—showing a saving of seventy-five per cent. By the introduction of the condenser, with Apperley's feeder, the old processes of scribbling, carding, and slubbing, are brought into a continuous line, and the use of the slubbing billy done away with, with its attendants—namely, one man and two or three

children. The ordinary spinning frame or mule requires one man and two girls to attend it; it is being superseded by the self-acting mule, which does away with the man's labour, two girls alone being required in attendance. The yarn spinning and doubling machines, dispensing with mules for that purpose, are expected to effect a great saving in space and wages. The weaving done formerly by hand is now worked chiefly by power. For woollen goods, the power-loom has comparatively been but recently introduced. The most important advances have been made since 1851. At that time, the power-loom was only adapted to produce plain goods, and certain patterns of not more than two or three colours of weft-thread. By the improvements since made, almost any description of pattern and variety of colours can be easily brought out. The shuttles are now so arranged, by the use of rising and revolving boxes, that any colour may be woven in which the pattern requires, and the fabric itself may be produced with greater rapidity and evenness. Girls are chiefly employed to attend the power-looms, each taking charge of one or more, whereas formerly the attendance of men was required. The saving effected by the use of power-looms varies from twenty-five to seventy-five per cent. In the process of "milling," the introduction of the "fulling" machine in place of the old stocks or heavy mallets, has effected a saving of time, space, and power,—requiring only one-third of the space, and one-half the power. By the use of tentering and drying machines, a saving of seventy-five per cent. of wages is effected, in addition to the production of better colours and imparting a better "handle" to the cloth. These machines are, however, very expensive, and beyond the reach of small manufacturers. Similar remarkable advances have been made in the processes of finishing, particularly in cutting or shearing, and in pressing, which is the last stage. There is yet room for farther advances, and woollen manufacturers will no doubt exert themselves to cope with the cotton manufacturers. Cotton machinery, in fact, has been earlier in hand; it has already afforded useful precedents for imitation in woollen machinery; and there is a probability that it may be still further imitated with advantage, if not in all, at least in some of the stages of manufacture.

CHAPTER II.

PREPARING MACHINERY.

The contributions of woollen machinery to the Exhibition were comparatively limited, particularly in the English section. The foreign collection was larger than the English, and comprised, amongst various isolated machines, a consecutive series of preparing and spinning machinery, by

the largest French manufacturer, M. A. Mercier. Messrs. Platt Brothers & Co., the largest English constructors, in like manner exhibited a consecutive series of woollen machinery.

Wool is, in the first place, sorted or mixed by hand, when as many as ten or twelve different qualities are sometimes selected from one fleece. It is then ready to be scoured. The scouring or washing machine was exhibited; and the first to be noticed is Mr. Lee Norton's model of a drying machine, which acts very well, but has been objected to on account of its liability to take fire.

If the wool is burry, or filled with notes, these must be separated from it, and the separation is one of the most troublesome processes. The burrs, which are found in many kinds of wool—the wools from Australia and South America, for example,—are the seeds of a plant which abounds in many sheep-runs, and are about the size of a pea. When unrolled, some of them are two inches in length, and like saws. The chief desideratum is to extract them whole from the wool without injuring the staple. If they get broken or undone in the wool, it is almost impossible to separate them without injuring it.

Burring Machines.—A machine—an English invention, Calvert's patent—was exhibited by MM. Houget & Teston, of Verviers, Belgium, in which the wool is passed from the feed-rollers to a steel-wire covered roller, a covering resembling card-clothing, known as Garnet's patent; from which the wool is delivered to a large cylinder covered with combs, which lay hold of and pass the wool under a fluted roller, by which the burrs are caught and knocked off. The burrs pass away through a grate, and the wool is taken from the combs by a revolving brush moving at a higher speed. The objection to this machine is, that the staple is rolled by the brush into knobs or "strings;" but though it slightly injures the staple, it is capable of burring a considerable quantity of wool.

Messrs. Calvin & Goddard, of New York, exhibited a burring machine, which they call the "Mestizo burring-picker," in which the wool is shaken or teased until all the burrs fall away. The main cylinder is covered with bars set with small teeth, which take up the wool and deliver it to a small roller clothed with Garnet's card, over which a small fluted roller revolves, and, as in the Belgian machine, throws back the burrs into the chamber of the large cylinder, to undergo the process again. The dust is extracted from the wool through a perforated zinc casing over the cylinder, by means of an exhausting fan-draught. This machine occasionally breaks the burrs, and it strings the wool; its production is not considerable.

Messrs. Platt Brothers & Co. exhibited a burring machine on the principle of their improved Macarthy gin, in which the burrs are

separated from the staple in the same manner as cotton-seeds. In this machine no small-teeth combs are employed; the staple is passed uninjured, open, and free from the dust and strings produced by the other machines described. The delivery is at the rate of from 8 lb. to 12 lb. of clean wool per hour, which is not considerable, but is as much as that of other machines, in proportion to the power used. It is not necessary to pass the fibre through the machine a second time.

Teazing Machines.—In the next process, of teasing, the wool is passed over large cylinders covered with teeth, to prepare it for the carding engine. It is then oiled, for the purpose of softening it, and of preventing the short fibres from flying. Some teasing machines, as that of M. Martin, of Belgium, are fitted with a brush, to deliver the oil on the wool as it passes on the feeding board. M. Mercier exhibited a teasing machine of the ordinary kind. Messrs. Apperley & Clissold, of Stroud, Gloucestershire, exhibited a machine, in which the lubrication of the wool was performed on the feeding table of the first carding engine. It has not yet been much used.

Carding Engines.—Wool is passed through a series of three machines in the process of carding. There is, first, the “scribbler,” or breaker carding engine; then the “intermediate,” or second card; and the “condenser,” or finisher carding engine.

Messrs. Platt Brothers & Co. exhibited a set of three carding engines. The cylinders and the rollers are of iron, which is preferable to wood; they are more economical, as the cards last longer than with wooden cylinders. They are fitted with the balanced doffer-comb, the same as is applied in Messrs. Platt's cotton carding engines.

The first, or scribbler engine, is 60 inches wide on the wire, with a common hand-spreading travelling lattice, on which the wool is conducted to a pair of small feeding-rollers, which are guarded by an “angular stripper roller,” to prevent the wool lapping them. The wool is delivered to a serrated taker-in roller, which is of cast-iron, with a number of serrated flat wires, like fine saws, let into the circumference. The object of these teeth is to stretch the fibres in passing the feeding rollers until they are released, when they are passed over to a second licker-in, whilst burrs, or other impurities on the surface of the wool, in passing, are driven back by a fly or guard roller, with a number of longitudinal fins on its circumference, which revolves at a quick speed and picks off and discharges the burrs into a box alongside, at the same time clearing the points of the saw-teeth of refuse lodged on them. The wool having been taken on, in a fair condition, by the second taker-in, which is, in fact, a reception card roller, it is transferred to the breast roller, 27 inches in diameter,—not directly, but by means of a clearer roller, which

strips the card taker-in. The breast roller has two working rollers and two clearers, by which the wool is further divided and prepared for the main cylinder, to which it is conveyed from the breast roller by means of a clearer or angular stripper. The main cylinder is 45½ inches in diameter, and has four working rollers and four clearers to continue the carding process. These are followed by a “fancy” roller, the design of which is to lift up the grease and wool to the surface of the main cylinder; it is for this purpose covered with a brush of long wires, the surface of which travels faster than that of the cylinder. The wool thus raised is stripped off by the doffer, 22 inches in diameter, which is finally stripped by the vibrating comb. The fleece thus stripped from the doffer is formed into a sliver by being drawn through a revolving tube by means of a pair of rollers in front, at one end of the doffer, from which it falls upon an endless travelling cloth, which conveys it to the intermediate card. The scribbler card works 100 lb. of wool per day.

The sliver delivered by the scribbler card is formed into a fleece to supply the intermediate carding engine, by means of “Apperley's feeder,” which lays the sliver obliquely across the travelling lattice of the intermediate, doubling it back and forward from side to side, to form a continuous fleece. Thus, a great many ends are presented to the feed-rollers at a time, which is favourable for uniformity of substance. The wool is again treated by two 7-inch taker-in rollers, as in the first card, and is transferred to the main cylinder, 45½ inches, with four rollers, four clearers, and a fancy roller; thence it passes to the doffer, from which it is stripped by a comb, which discharges it as a thin fleece upon “Ferrabee's feeder” to the finisher carding engine and condenser. The object of this feeder is to lay and deliver the fibres crosswise to the finisher card, to be again straightened by the taker-in rollers.

Ferrabee's feeder is a system of travelling lattices, of which the upper one works at right angles to and traverses the lower, reciprocating from side to side; and deposits the fleece which it carries over from the intermediate, in a succession of thin layers, across the lower lattice. A sufficient thickness of wool being in this manner deposited, is delivered to the finisher carding engine from the lower lattice. This feeder answers excellently for mixing coloured wools before entering the finisher card.

The finisher carding engine and condenser is 42 inches on the wire; the card is the same in arrangement and dimensions as the intermediate card, with the addition of Fairbairn's condenser.

The object of the condenser is to divide the wool fleece, which is spread uniformly on the doffer, into parallel strips, and convert them into felted slivers or bands. The novelty of Fairbairn's condensers consists in effecting this separation by dividing the clothing of the doffer into

strips, parted by thin steel blades, which are stationary, to divide the fleece as the doffer revolves towards them. The divided fleece is stripped by a smaller 3-inch doffing roller in front of the larger doffer, and the strips pass between two endless sheets of leather, or rubbers, which are stretched on pairs of rollers hung in frames, having a transverse alternate motion. The strips are by this means formed into slivers, or condensed, and are delivered to a double row of bobbins, one above the other, to receive the alternate slivers, and to complete their separation from each other. They are wound on the bobbins by surface contact with two revolving rollers. The condenser delivers forty good slivers or threads, with two waste ends, at the sides.

Messrs. Apperley & Co., of Stroud, Gloucestershire, exhibited their diagonal feeding apparatus, which has been described with the machinery of Messrs. Platt Brothers & Co.; also a self-acting apparatus for oiling the wool at the carding engine, and a condenser.

Messrs. Ferrabee & Co., of Stroud, exhibited their double-lattice feeder, just described.

M. Mercier exhibited three carding engines, having 50-inch cylinders, with five workers, and five strippers about a fourth of the size of the workers. The strippers are very small, and woollen spinners have various opinions as to what are the proper sizes of rollers and workers. The cylinders are built of wood; all the other carding cylinders exhibited were made of iron—a material now in general use for rollers and cylinders on the Continent, particularly in Belgium and Prussia, as well as in England. Apperley & Clissold's feeder is used. With these, a novel wool-combing machine was exhibited; but it was very seldom at work.

Messrs. Houget & Teston exhibited a set of two carding engines with iron cylinders, mounted with six rollers and six strippers.

M. Martin, of Pepinster, Belgium, exhibited a set of carding engines, the principal novelty in which was the application of a second fancy roller on the top of the cylinder. Both fancy rollers are small sized, but the idea is a good one, and might with advantage be frequently adopted. The cylinders, doffers, &c., run in bearings with rocking bushes, to adapt themselves to the shaft—a plan which is only useful when exactness of workmanship is wanting. The bearings of the workers and strippers are covered, to keep them clear of flying wool. The feeder is somewhat like Ferrabee's; the wool is received on an endless cloth web, to the requisite thickness, when it is wound off upon a roller.

Mr. Hartmann, of Chemnitz, Saxony, exhibited a set of three carding engines, in which the cylinders and rollers were much smaller than in the other machines. The mode of feeding is that of the drum, common on the Continent, in which the wool from the first card is rolled on a large drum. When the desired thickness of fleece is attained, it is cut across, at two places,

into two equal lengths, each of which is equal in length to the width of the next feeding board, upon which the pieces are placed crosswise, in order to present the fibres sidewise to the feeding rollers. In some instances the drums are self-acting, so that when a given number of revolutions have been made, they open outwards, and so break and unroll the fleece. But the drum system is clumsy and wasteful, and requires a good deal of attendance.

Condensers.—Besides Fairbairn's condensers, four others were exhibited by Mr. Apperley, Messrs. Houget & Teston, M. Martin, and M. Mercier, known as double-doffer condensers. In all of these, two stripping rollers are applied, consisting of alternate stripping-rings and blanks. The first roller takes off alternate strips of wool from the doffer, and the second roller takes off the remaining strips. Difficulty is experienced in getting the strippers to take off equal strips of wool, as the first is likely to strip more than the second, especially if the wool be long and strong in fibre. The objection could be remedied by suitably proportioning the stripping surfaces and blanks; but this would require very frequent adjustment, as wool is prepared in parcels or batches of different kinds, weighing only 240 lb. each. The practical result is, that the upper bobbins of wool from the condenser usually require to be spun on one mule, and the lower bobbins on another.

Piecing machines, of which no examples were exhibited, are used at this stage of the process in England. They are never used on the Continent.

CHAPTER III.

SPINNING MACHINERY.

Mules.—M. Mercier exhibited a hand-mule in operation. It was deficient in construction and workmanship, and was much inferior to hand-mules made in England.

Mr. Mason, Rochdale, exhibited a self-acting mule, which was pretty well adapted for fine spinning, but was too light in its parts for general usefulness. The various and numerous changes necessary for wool-spinning, are made in this mule by means of straps working on reverse cones, which, with such short lengths of strap as are available, do not give by any means positive motions. The mule is fitted with a double-speed, which is advantageous, as it is desirable whilst the thread is being drawn to twist it just sufficiently to prevent its breaking, and to make up the additional twist when the carriage arrives at the end of its stretch, for which purpose the speed of the spindle is increased.

Messrs. Platt Brothers & Co. exhibited a self-acting mule, substantially constructed, embodying

several improvements, and adapted for the varied work of wool-spinning. The "double speed," or slow and fast motion, is applied with two rims, the change being obtained by a traverse of the strap and two rims, without the aid of either countershaft or gearing; the rim out of action in either case being converted into a carrier pulley, and retaining the double-banding arrangement. There is a motion for giving out the necessary length of slubbing to be spun, so connected with the cam-shaft as to work the delivery rollers simultaneously with the drawing-out motion. To prevent the breaking of threads during the process of twisting, when they become shorter, a receding motion is applied, which slowly draws in the carriage one, two, or more inches, according to the fineness of the yarn and the degree of twist. The length of the draw of the carriage is regulated in accordance with the running up of the yarn and the recedence of the carriage.

M. Mercier exhibited some spinning machinery resembling the throstle used in spinning cotton, on a system to which many English spinners of wool are directing their attention. The sliver or rove from the condenser-bobbin is drawn between two pairs of rollers at about 18 inches apart. In the intermediate space, two small rollers with fan-like blades are applied to beat and loosen the thread, and to facilitate its being drawn. The twist is given after the thread leaves the second pair of rollers, from which it is wound on a bobbin by an ordinary flyer, or, as in M. Mercier's machine, in the form of a cop, by the "ring and traveller motion." The thread produced in this manner is "wiry" or close; and the machine has not been found to work well on very coarse or very fine sizes of yarn.

M. Mercier exhibited a machine for the production of "*filés feutrés*,"—threads which are not spun, but felted. The sliver from the condenser is drawn into yarn by being rubbed between a series of rollers covered with linen cloth. The thread, during the process, is moistened by steam, the wool having, in the preliminary stages of manufacture, been damped by a solution of soap in water,—not oiled. Under this treatment, the larger and coarser fibres form the core of the thread, and are enveloped by the finer fibres, which improves the appearance of the thread, making it look finer than it really is. This process is serviceable in working a mixture of two qualities of wool. Beautiful specimens of cloth made from this kind of yarn were exhibited in the French court. It remains to be proved whether this machine will work economically: the linen covering for the rollers is subject to considerable wear and tear.

Twisting Machinery.—Twisting or doubling is generally done on a common mule with a

uniform instead of a differential motion for drawing out. Several machines for this purpose were exhibited, but none of them were at work.

Hosiery Machinery.—Messrs. Maclea & March, Leeds, exhibited a system of machinery for short hosiery wool, consisting of three frames,—a cone drawing frame of eight spindles; a cone finisher frame of sixteen spindles; and a cone roving frame of fifty-four spindles. They were fitted with helical gill-heads, through which the sliver or roving passes between the retaining and the drawing rollers; and with a cone and differential motion for regulating the speed of the bobbins, so as to wind on the roving as it is delivered from the drawing rollers, without tension or drag. The sliver from the carding engine is passed through the gill of the drawing frame, where it is drawn to from five to eight times its length, slightly twisted, and wound on bobbins. Three or more rovings from the drawing frame are passed through each gill of the finisher frame, and again drawn to from five to eight times their length, with a little additional twist, and wound on bobbins. Two rovings from the finisher are passed through each gill of the roving head, again drawn five to eight times, and twisted a little more. Thus the preparation for the spinning frame is completed. The principal improvement is the self-regulating winding motion for the bobbins, by means of which the breaking of the sliver or roving is prevented. On the ordinary system, of "drag-roving," the rove has to drag the bobbin, as in the throstle for cotton, and frequently breaks in consequence, particularly if of short wool.

Conclusion.—The superiority of the wool machinery exhibited by Messrs. Platt Brothers & Co. in design and workmanship has been generally admitted. Ferrabee's feeder was remarked for the perfect manner in which it mixed and equalized the staple, and its thorough adaptation for working mixtures of coloured wool to produce a uniform shade. Fairbairn's condenser, also, was very simple in its details, and strongly contrasted with the foreign condensers, which were loaded with wheels and other gearing, much of which was not essential, whilst it made the machine heavier to drive than Messrs. Platt's, and was noisy and clumsy in action.

The second fancy roller employed by M. Martin was a noticeable and creditable addition to carding engines,—that is to say, the use of two in succession on the same cylinder, instead of one only as in the other cards. Since the duplicate fancy rollers were exhibited, the design has been carried out and tried by some English manufacturers, who have reported very favourably upon their performance.

SECTION III.

MACHINERY FOR PREPARING AND SPINNING FLAX, HEMP, AND JUTE.

CHAPTER I.

INTRODUCTION.

The scarcity and high price of flax for several years past induced manufacturers, particularly those who manufacture the lower qualities of linen yarn and cloth, to introduce more extensively the cheaper material, hemp; and also, more especially, jute, by means of which the requirements of trade have been met to a large extent. It appears, indeed, from the report of the Jury on Class 19 (Flax and Hemp), that the manufacturing industry of flax and hemp has remained almost stationary during the last eight or ten years, whilst the manufacture of jute has been rapidly extended. Though flax, they remark, is a material most easily adapted for spinning yarns, being producible by hand labour quite equal to silk in fineness; and though the raw material of flax in the state of fibre is about the same in price as the better kinds of cotton, yet the yarns produced from flax by machinery appear to cost more. It is only with the greatest difficulty that flax-spinners have been able to produce by machinery yarns of extreme fineness. The greater cost of flax yarns arises from the practical difficulties of converting and working the raw material. The great obstacle in the flax fibre is the excessive quantity of gum which it contains, and which is not thoroughly extracted by the ordinary steeping process resorted to, to purify and soften the fibre. When this obstacle can be removed, flax may probably be as easily and as finely spun as cotton. Under existing conditions, flax machinery is required to be made decidedly stronger than cotton machinery, and more power is required to work it, in consequence of its greater resistance to sliding and drawing,—the basis of all spinning operations.

The fibres of hemp are inferior to those of flax in softness and minuteness, and are still more difficult to spin. Jute, besides being very cheap, being sold at prices varying from 2½d. to 5d. per lb., can be more freely spun; and this may account for the rapid progress made in jute manufactures. Dundee is the principal seat of this rising manufacture; the raw material is employed there, either pure or mixed, to make ordinary brown cloth, but more especially sack-ing, packing-cloth, and carpets. The jute yarns used for carpets are of the richest and most varied colours, and are sometimes used in conjunction with cocoa fibre. The consumption is reported to have reached 40,000 tons annually; and there are upwards of 35,000 spindles at work on jute in Dundee and its neighbourhood.

The manufacture of rope and cordage by machinery has occupied the attention of manufacturers during the last fifteen years. The machinery exhibited for preparing and spinning hemp into rope was of recent introduction, and it excited general interest. Where it has gained a footing, machinery has led to the abandonment of the old hand-process—spinning and laying in the ropewalk—which is still followed in many places exactly as it had been for centuries practised by our ancestors.

Flax, hemp, and jute, are spun with machinery on the same principles, but with differences in size and proportions.

Tropical countries abound in plants containing very valuable fibres suitable for textile purposes, which would be largely used in manufactures, if the fibre could be economically extracted. The leaves of the aloe, the plantain, and the pineapple, possess an abundance of fibre, which is, in the green state, of the most valuable quality. The ordinary processes for separating fibre from green plants are primitive and rude,—pounding with a mallet, scraping with a sharp stick, or rib-bone, or piece of hoop-iron, and washing in water, by which a few pounds of fibre, like Sisal hemp, or the pineapple, are extracted—the produce of a day's laborious work. The fibres of plants are naturally white and soft whilst the plants are in a green or growing state, and only become discoloured and hardened by desiccation or decay, or by exposure to the atmosphere after being cut. The juices and gums which envelop the fibres become chemically changed, and fixed in the fibres; and the fibres must be bleached and softened for manufacturing purposes. The juices and gums are, in the green state, soluble in cold water; and it has been found that if the leaves or stalks be subjected to a combing and hackling process, with a free application of water, the extraneous matters are washed away and the pure fibres remain. A machine based on this principle was exhibited, and will be described in the following chapter.

CHAPTER II.

FIBRE-EXTRACTING AND SCUTCHING MACHINES.

Sandford & Mallory's Fibre-extracting Machine.—A couple of small and unassuming machines from the United States, the invention of Messrs. Sandford & Mallory, were exhibited by Mr. Alexander Guild,—one for scutching flax, the other for extracting the fibre from the

cylinder is 30 inches diameter, and the breadth of feed is 16 inches; the weight is 11 cwt., the required speed 80 to 90 revolutions per minute.

Flax-scutching Machines.—Messrs. Sandford & Mallory exhibited a scutching machine, which was the same in principle and construction as the fibre-extracting machine: it was the first of the kind that was made, which may account for its inferior construction and rather slovenly performance. The cylinder is 20 inches diameter, with a 26-inch feed. The cylinder is an open framework of four iron rings, which carry the beaters and scrapers. The endless band is composed of strips of leather which carry the beaters and scrapers, and allow the boon or shove—the hard brittle substance separated from the fibres—to fall through, whilst the tow, or waste fibre, is thrown out at the end. The flax, retted in the usual way, and unbroken, is held in a light wooden holder, and delivered in a thin layer to the feed-rollers, from which it passes to the cylinder to be stripped, like the fibre-leaves in the other machine, but without the use of water. It is stated that a boy and two children can strip 100 lb. per day. Flax scutched by this machine is produced even and unbroken, with clean ends; the produce of fibre is 20 per cent. of the gross weight of the straw, and it is stated that the yield, on the hackle, of flax scutched by this machine, is larger than that of flax scutched by other processes. The power required is half a horse-power. A speed of 150 revolutions per minute is sufficient for ordinary retted straw, and the speed is varied by means of change-wheels.

Messrs. John Rowan & Sons, of Belfast, exhibited a flax-scutching machine, which has raised considerable expectations, and was much noticed in the Western Annex. It has the cylinder in two parts on one shaft, 3 feet in diameter, and each about 8 inches wide, with ten beaters and one comb distributed upon the circumference. The beaters are hinged to the cylinders, for the purpose of giving way slightly on striking and breaking the straw. The comb has eleven triangular teeth, which keep the fibres open and allow the beaters to scrape off the boon or shove. The cylinder makes 400 revolutions per minute for average qualities of straw; it is moved faster for hard and wiry straw, and slower for soft straw. It is worked by two persons, and will clear from 150 lb. to 160 lb. of flax per day. A “strick” of flax straw is passed quickly into the opening, where it is subjected to the action of the scutcher. It is then withdrawn slowly, turned over, and again introduced. Then it is reversed, and the other end treated in the same manner. The shove falls through the machine, and the tow, or “fly,” is collected at the back. The average yield by this machine is stated to be 25 per cent. of flax, 14 per cent. of tow, and 61 per cent. of shove. The tow is used for the manufacture of sacking.

This machine is similar in its mode of action to the old-fashioned “scutching handles,” in which the knives or beaters revolve on an axle, and the flax is presented to their action over the edge of a board, or through a slit. The average yield by ordinary scutching, in this manner, is 19 per cent. of flax.

M. Mertens, of Gheel, Antwerp, exhibited a machine for scutching flax and hemp. Two systems of beaters revolve on two axles, making 100 revolutions per minute, between which the straw is introduced, and is struck alternately on one side and the other. The straw, previously broken, is fixed in and sustained by metal clamps; and is reversed after one end of the strick is cleaned. The machine is worked by eight attendants, and the produce is stated by the exhibitor to amount to 50 lb. per man per day.

Messrs. Rowan's machine is found to be best adapted for dealing with rough strong flax-straw, which is strong enough to resist, without injury to the fibre, the beat of the knives: these, though they are hung on centres, strike, at high speeds, with a hard beat. The machine is too severe upon the finer qualities of flax, breaking the fibre, without entirely cleaning it; whilst the flax requires, in many cases, to be passed again through the old machine. The constructors have recently introduced some improvements, in which they reverse the motion of the cylinder and feed from the side. M. Mertens' scutcher requires the flax to be broken for it, which is objectionable; and it has not been found to give satisfactory results at Belfast, where it has been tried. Messrs. Sandford & Mallory's scutcher operates differently from either of the others in not having a hard beat, the flax being, in a manner, lapped round the cylinder, and exposed to the action of the beaters or scrapers through half the circumference. The principle of this machine is likely to prove satisfactory, and to provide for breaking and removing the shove without injury to the fibre. But before this object can be fully attained by the machine, particularly the breaking of the straw, it would require to be better made and better detailed.

Messrs. Sandford & Mallory have recently introduced a machine for breaking flax and hemp straw, which acts by percussion and by rubbing, and is different in principle from all machines now in use for that purpose. In existing machines, rollers of various forms are used for breaking or bruising the straw previously to scutching,—mostly heavy, fluted rollers, acting more as crushers than as breakers, which do not remove any of the shove from the fibre. But the new breaker consists of two pairs of peculiarly fluted rollers, having a rapid reciprocating rotary motion, vibrating further forwards than backwards, whereby the straw is led through by degrees into the machine. The rubbing and crushing action thoroughly breaks and loosens

the boon, and the machine is said to be capable of breaking 25 cwt. of flax-straw per day. It removes from 30 to 60 per cent. of the shive. What remains adheres so lightly that a slight scutching clears it, and thus a large percentage of unbroken fibre is obtained. For really practical use, there is no scutcher in existence equal to the common scutching handles, or "mill-stocks," which are almost universally used in Ireland; and what is most urgently required to make them complete is a machine like the one described, for thoroughly breaking the straw previously to its being placed in the scutcher, that the fibre may be more mildly treated.

As for scutching machines, what is wanted is, not a machine for large mills and factories, but a cheap portable machine, suited to the wants of the farmer. In a good season the existing mills cannot overtake the work, and flax lies occasionally twelve months before it can have its turn at the scutchers.

CHAPTER III.

FLAX MACHINERY EXHIBITED BY MESSRS.
SAMUEL LAWSON AND SONS, LEEDS.

Messrs. Lawson & Sons exhibited a system of preparing and spinning machinery for flax, with rope-spinning machinery.

1. *Flax-dressing or Hackling Machine*.—This machine is double; it is on Horner's system, with six tools, adapted for dressing long flax from twenties to thirties. It is of the intersecting kind, dressing both sides of the strick at once. The hackles do not dress so closely up to the holder, nor cut so well, as in Lowry's machine. The chief advantage consists in the method of stripping the tow from the pins, in which wood stripper rods are used in place of the ordinary brush and doffer; the rods do not go round the entire sheet, as in the old flat or oblique machines, but revolve with the lower sheet wheels, falling in behind every hackle on the sheet, and clearing the tow with them in the course of revolution. Loose tow fibres that escape the strippers are caught by a row of long pins or "tow-catchers," which are turned over at every descent of the trough, to let fall the tow collected by them.

2. *Carding Engine*.—This engine is for tows for forties to fifties yarns. It has two doffers, eleven pairs of rollers, and one feeder with concave bar; the concave bar is sometimes used for feeding short tow instead of the second feeder, in order to feed closer up to the cylinder. The rollers have the ordinary leather clothing, and the cylinder with the pins set in wood segments. Wood clothing is of recent introduction; it is cheaper and more easily repaired than leather. The dead wood and the elastic leather work

well together, fully as well as wood and wood, or leather and leather. The slivers pass over a circular gill drawing-head, thence with a short draught to the drawing rollers, thence to the delivery rollers, where the slivers may be united so as to fall into one can.

3. *Grimston's Balling Machine*.—This machine, for thread or twine, differs from the ordinary machine in nearly all its movements. In the ordinary balling machine the uncertainty of the weight of the balls or clues when on the spindles is a source of trouble and delay, as they require to be pulled off from time to time to check the weight, and final exactness of weight is not always arrived at. For the purpose of regulating the size and weight of the ball, the new machine is fitted with a graduated index-plate, with a pointer, which is fixed on the end of a shaft carrying two cams, one underneath the spring handle, the other in connection with the belt-fork. The pointer having been set to the number on the index-plate corresponding to the size of ball required, the machine is set in motion, and the cams and the pointer are moved round until the spring-handle is lifted out of the notch by which it is retained. The spindle-frame being thus set at liberty, it is pulled round by a weight to the proper angle to receive the cover or last layer of thread; when this coating is completed, and the ball has attained its full weight and dimensions, the belt is thrown off by means of the second cam, and the machine is stopped. The machine is fitted with three spindles in place of two, the usual number, for which the driving tapes are suitably arranged. The degree of closeness of the winding is readily adjustable. It may be all close, or all open; or it may be open until the last layer is applied close and compact.

4. *Self-acting Yarn Reel*.—This machine has the side cam and balance lever to stop the swift when the yarn breaks, or at the end of a lea, similar to the self-acting stopping motions in cotton-spinning machines. It is divided into heads of five bobbins each, with one attendant to four heads. The collapsing motion of the swift is the invention of the late Mr. Edward Lawson and Mr. G. Jennings. To remove the yarn in ordinary reels, it is slackened off by collapsing the swift on its entire circumference. In Messrs. Lawson's reel the same object is effected by collapsing only one segment, which simplifies the construction.

The rope machinery exhibited comprised a spreader and spinning frame.

5. *Spreader*.—The spreader is of the usual construction, having two slivers, one as a first drawing, the other as a second drawing, with screw gills. The front rollers are not turned out of solid wood as usual, but have a hollow iron roller shrunk upon the axle, with wooden

lags or segments fastened to it, which makes a more lasting roller. A pair of small rollers are placed close in front of the drawing roller, to prevent the wiry fibres lapping on it. The drawing rollers are weighted by means of a parallel motion, designed by Mr. John Lawson and Mr. Stephen Cotton, to keep the centres of the rollers in a vertical line as they become reduced in size by the trueing-up process. The motion acts very well, and supersedes the old plan of guide-slots or levers.

6. Spinning Frame.—This frame has four vertical spindles driven by broad leather belts in preference to gearing, to reduce the wear and tear, and the liability to breakage at a high speed, when a considerable degree of power is required to drive large spindles with heavily dragged bobbins. If the ordinary nipper be choked by lumps in the yarn, and the spindle is unable to pull them through, the belt slips and saves breakage. But the new nipper, betwixt the drawing roller and the spindle-head bar, is so put together that the top rests on the bottom cross-bar, and continues to do so, whilst the yarn passes through of the right size; though the top gives way freely and is slightly raised to pass lumps or irregular thicknesses in the yarn. Whereas, by the old method, the top is held down by means of set screws and springs, which are not so delicate in action. If the spindles make 800 revolutions per minute, spinning twenties yarn weighing $3\frac{1}{2}$ lb. for 170 fathoms, they would turn off about 300 lb. per day—as much as is spun by three men in the ropewalk. At a higher speed more yarn can be turned off; but better yarn can be produced at the lower speed with less wear and tear of the machine.

CHAPTER IV.

FLAX MACHINERY EXHIBITED BY MESSRS. JAMES COMBE AND CO., BELFAST.

Messrs. Combe & Co. showed machinery for hackling and preparing flax for yarn from 30 to 60 lea, a tow-lap machine, and cop-winding machines.

1. Long-line Hackling Machine.—This machine is six-tooled, 6 feet wide for long line flax, with lifting holders. It has vertical sheets, and, instead of the ordinary sheet-bars, the hackle-stocks are fixed on the sheets, which thus run lighter, and may be driven at any speed without noise or vibration. The tow is stripped off the hackle-pins by means of stripper bars that fall into the spaces between the hackle-stocks whilst cutting, and rise from them at the outside of the sheet,—superseding the brush and the

doffer, which are unnecessary, except for very fine work. This machine is simple and effective, and hackles close up to the holder; and it is capable of doing a great quantity of work.

2. Long-line Spreader.—This is a spreader or first drawing with six slivers for long-line flax, for 30 to 50 lea yarns. The machine is suited for working in the manner which has lately come into extensive use in Ireland, for making first-class yarns, the main feature of which is to produce a uniform and level yarn by light spreading and a great number of doublings. There is a good arrangement for receiving the fallers as they pass from the upper to the lower screw.

3. Drawing Frame.—Second drawing, of two heads with six slivers each. To complete the system, there is a third drawing frame, of three heads, with eight slivers each, which was not exhibited. It precedes the roving frame.

4. Roving Frame.—This is a frame of 60 spindles, for bobbins 8 inches by 4 inches. It completes the system of preparing machinery. The principal novelty consists in the use of an expanding pulley, the invention of Mr. James Combe, for varying the speed of the bobbin as the rove is wound upon it, instead of the usual conical drum. The pulley consists of a double cone, or more properly of two interlocking cones, in the groove formed by which the driving-band runs. The diameter of the working groove is varied, and consequently, also, the speed of the bobbins driven from it, by bringing together, or by parting the cones. By means of the expanding pulley, a more complete and better bobbin is made; it gives a steadier motion than the conical drum, upon which the belt is liable to slip, and a perfectly regular take-up of the rove by the bobbin after leaving the front roller, without draught, which is of great importance for the long fibres in flax slivers. In the expanding pulley, the driving band works and bites in a wedge-form groove.

5. Tow-lap Machine.—The function of this machine is to wind tow slivers into a lap 24 inches diameter by 20 inches wide, for feeding carding engines. It is driven from the centre, and not, like most other machines, by surface contact, which ensures a regular and firm lap. It is fitted, like the roving frame, with the expanding pulley, to decrease the revolutions of the lap as the diameter is increased, maintaining the surface at a uniform speed. In other machines, the speed is reduced abruptly, and but once, by shifting the belt to another pulley working into slower gearing.

6. Cop-Winding Machines.—The object of these ingenious machines, which are on Combe, Smallpage, & Combe's patent, is to do away entirely with the wooden "pirns," or spools, em-

ployed to receive the yarn, by winding it direct on the spindles. The 6-inch pitch machine is as made for coarse work ; it contains 24 spindles, to make cops 2 inches diameter and $10\frac{1}{2}$ inches long ; the finer one has 40 spindles 3 inches pitch, to make cops $1\frac{1}{4}$ inch diameter and $6\frac{1}{2}$ inches long. The yarn is laid on to the spindle with a short quick traverse, giving the starting end of the cop a conical form. The cop presses with its conical surface in a conical cup, having a slit down one side for the introduction of the yarn to form the cop. As the cop grows, in the conical cup, it depresses itself and the spindle until it has acquired the proper length, when it presses down a stop-wire, and disengages the spring-clutch which stops the spindle. The pressure on the cop during its growth communicates to it the compactness and solidity necessary to keep it in shape after the spindle is withdrawn. The cop when finished is a hollow cylinder, conical at the end, with a hole the size of the spindle ; and the yarn may be unwound either from the inside or the outside. The spindles are driven by gearing ; each spindle is complete in itself, and independent of the others, and stops when the yarn breaks, before the end disappears in the cup.

The cops made by these machines may be used for warp or for weft. For weft, they are packed tightly into the shuttle, lengthwise and laterally ; and two and a half to three times the quantity is thus charged that can be got in on the ordinary pirn or spool. The running-off of the thread is smooth, and the delivery is not checked as commonly happens with pirns when nearly run out by the coiling of the weft round their stems ; preventing, accordingly, loss of production by stoppages, and irregularities in the selvages of the cloth. The new cop also is formed at a less cost than the old one, and does away entirely with the stock of weft bobbins otherwise indispensable. When used for warps, the cumbersome and unwieldy bank or bobbin-creel is not required ; its place is supplied by a solid wall of cops facing the back of the warping or dressing machine.

CHAPTER V.

ROPE-SPINNING MACHINERY.

Messrs. Peter Fairbairn & Co., of Leeds, exhibited a system of substantial rope-spinning machinery, either for Manilla or Russian hemp. A spreading table of two slivers ; second drawing of four slivers ; gill-spinning of four spindles for heavy yarns, and one of eight spindles for the lighter sorts,—say, from thirties to forties, cable yarn. Two reception cans are placed in front of each head or carriage for the purpose of receiving the fallers or hackle-bars as they are lowered to the bottom screw,—preventing noise and wear of slide ends with heavy fallers. The spindles are driven by gearing, which makes a uniform twist. In the fine-spinning frame two kinds of front pressing rollers are shown,—of wood ; and of leather in strips on edge, bound together with a bolt and nut. At Chatham dockyard, where many of these machines are at work, wood is considered to be the best material for the pressing rollers of first and second drawings, and leather on edge for those of the spinning machines.

Mr. George H. Sanborn, of Boston, U.S., exhibited a rope and cord making machine. The rope is formed by twisting a number of strands together, according to the thickness of the rope required. The machine exhibited was constructed for nine strands, which were carried by and wound on bobbins hung in groups of three, on three flyers, each flyer having three spindles or bobbins, and being driven separately from the main shaft by gearing. The flyers rotate in the direction opposite to that of the twist originally imparted to the strands, thereby “rapping” the rope,—making two opposite twists, which induce the strands to grasp each other, and prevent any tendency to unloose. The three threefold strands thus produced are twisted round each other again in a reverse direction, and a second rapping is effected ; after which the rope is received on a roller.

SECTION IV.

MACHINERY FOR THE PREPARATION AND SPINNING OF SILK.

Silk machinery is very simple and very tiny. There is no preparatory machinery required for silk as there is for cotton. Silk is imported into England in hanks, wound direct from the cocoons, occasionally thousands of yards in continuous lengths. But silk is measured by weight, not by length. The most important and most extensive series of machinery for the manufacture of silk was exhibited by Messrs. Wren and Hopkinson, of Manchester.

1. *Silk-winding Machine*.—The object of this machine is to wind the silk from swifts of 32 inches diameter, as used for the winding of silk from Italy and Bengal. The machine is made with from 90 to 100 spindles, on which the bobbins are fixed ; they are placed horizontally, and are turned by friction-wheels on a winding shaft, which makes 40 revolutions per minute, and turns the bobbin spindles 200 times per minute. Should the silk be entangled, the bobbins being

driven only by friction, are stopped without breaking the fibre, until the silk is examined and rectified. The bobbins are 2 inches in diameter and $2\frac{3}{4}$ inches long, and there is a differential motion by a sun-and-planet arrangement with a crank motion, to traverse the fibre on the bobbin and cross the silk, and prevent it "cutting under" at the ends. For the long hanks of strong silk, imported from China, a larger machine, known as the "Canton machine," is used, suitable for swifts of 48 inches.

2. Silk-cleaning Machine.—There are thick portions in silk fibre, which may be two or three yards long; and it is needful by means of this machine to detect and remove irregularities and knots in the thickness of silk after it is wound. Bengal silk usually requires this treatment. For this purpose the silk is passed from the winding bobbin to the cleaning bobbin between the edges of a steel cleaner; being, in fact, a slit, adjustable by screws to pass the maximum thickness allowed, and to intercept fibre of extra thickness. The attendant breaks off the intercepted portion and rejoins the thread by a knot, which is not found objectionable amongst a number of fibres. The action of the silk cuts the edges of the slit and destroys its function; and, in place of the slit, a pair of adjustable horizontal steel rollers are in some cases employed, which are better. The fibre is traversed on the bobbin by means of mangle-wheel gear, driven by the bobbin shaft, from which an alternate motion is given to a sector, driven by a pinion on the mangle-wheel shaft; from the upper end of the lever carrying the sector, a pair of slide rods receive an alternate motion, carrying with them the glass rings which guide the fibres to the bobbins. But the traverse must be varied in extent, to prevent the fibres from cutting under; and to effect this variation of traverse, the centre bearing of the lever which carries the sector is placed on an axle with eccentric bearings, which being slowly revolved by a worm motion not coinciding with the periods of traverse, the centre of the lever is thrown over a little to one side and the other, varying thus the traverse of the thread.

3. Silk-sizing Machine.—This machine is usually made with 12 bobbins, on Atwood & Leigh's patent. It is ingeniously contrived to assort the silk into four sizes, according to the thickness of the thread, as silk naturally tapers from end to end of the cocoon. The fibre is passed successively right and left, over and between a series of seven rollers, arranged vertically upon each other, and separately balanced on the ends of counterweighted levers. The object of the successive passage of the fibre between these rollers is to multiply six or seven times any change of thickness, to render it obvious at the end of a long index-lever, which

rises or falls, and is forked, with two pins, which vibrate behind a notched upright bar, and support it vertically, until one or other pin arrives at a notch on one side or other of the bar. The bar falls back, the pin slipping through, and lets go a lever, which lifts the receiving bobbin off its bearings on the driving friction-wheel, when it stops. The bobbin is then changed, and the fibre passed to a fresh bobbin. The main driving shaft makes 40 revolutions per minute, and the receiving bobbins 160 per minute.

4. Spinning Machine.—This machine is made with from 200 to 500 upright spindles, which make 4,500 revolutions per minute. The object is to spin or twist the single threads of raw silk before doubling them. The bobbins from the sizing machine are placed on the upright spindles and revolve with them; the silk fibre is withdrawn from the bobbins, and makes a turn round an intermediate roller, to preserve the twist, which is put into the fibre at the rate of twenty twists per inch of length, and passes on through a glass guide to the larger bobbins, $2\frac{1}{2}$ inches in diameter and $3\frac{1}{4}$ inches long, placed horizontally, and turned by gearing to ensure regularity of twist. Sometimes the horizontal bobbins are turned by the friction of their own circumference on small rollers covered with cloth; and the upright spindles are turned by the friction of an endless strap, passed round the machine, and directed to rub against the spindles. This mode is specially applicable for the purpose of crape-spinning. The traverse of the twisted fibre on the bobbin is effected by means of a pair of oval wheels, which give a uniform speed of traverse and a straight bobbin. The upright spindles are ranged in two or more rows, with a tin roller between them, from which they are driven by cords, as in the cotton-spinning frames.

5. Doubling Machine.—The doubling machine winds and lays evenly together two or more threads of silk from the spinning machine, preparatory to their being twisted together in the throwing machine. The main shaft makes 50 turns per minute; the bobbins, turned by friction, 200 turns per minute. There is a self-acting contrivance, not unlike the balanced levers of the cotton-drawing frames, for stopping the required bobbin when any one of the contributory fibres breaks; in this case, the attendant pieces up the broken thread, and sets the apparatus again in gear.

6. Throwing Machine.—On this machine the doubled threads are twisted or spun together, their bobbins revolving on upright spindles, as in the spinning machine, and making from 3,000 to 4,000 turns per minute. The spun threads are wound on reels 43 inches in circumference, fifteen to each reel; and there are from six to twelve reels on a frame. As each reel is filled, it

gives notice by striking a bell. Silk is sometimes thrown by means of the spinning machine,—the silk being reeled into hanks on a reeling machine, by hand or power.

7. Stringing or Glossing Machine.—This machine is designed for straightening and stretching silk, wool, or cotton, in hanks. The yarn is confined in a steam-tight case, and stretched between two crooks, one of which is secured to the upper part of the case, and the other is in direct connection with a piston in a cylinder with a steam pressure of 30 lb. per square inch upon it, as the stretching force. By the direct action of steam, a powerful strain is more promptly brought to bear upon the yarn than by the method of screws. At the same time, a jet of steam is thrown into the case to heat the material, and gloss the silk threads whilst under tension. This machine is designed specially for operating on silk, which becomes permanently stretched a tenth of its length.

8. Soft or Dyed-Silk Winding Machine.—In this machine, silk thread is wound from the dyed hank on bobbins, making 200 turns per minute, in readiness for warping or making into shuttle-pirns by hand or by the pirn-winding machine. As in all the other winding machines, it is of importance that the thread should be wound upon the bobbins, to prevent the ends from cutting under; and for this purpose a motion is employed, like that already described, of a lever with a shifting centre.

Messrs. Wren & Hopkinson exhibited also an assortment of machinery for manufacturing cotton and sewing thread, as follows:—

9. Throstle.—There are two novelties connected with the working of the top rollers, of which there are three. In the first place, instead of the fixed grooves cut in metal, the ends of the rollers are guided by and turned between a pair of disc surfaces, capable of being turned or shifted round on their centres, so as, when worn, to present fresh unworn surfaces to guide the rollers. Again, the top rollers are held down by weights slung in endless bands, which revolve upon the bearings of the rollers, to do away with the friction of the dead-weights hung on the usual stationary hooks. The bolster-rails are moved by a novel arrangement of a mangle-wheel and quadrant motion, which effects a balance of the rails on the two sides of the machine; and by means of the curves of the lifting quadrants, the barrel-shape of the full bobbin is said to be produced more correctly than from the ordinary heart-motion. The feet of the spindles run in steps which are conveniently adjustable when worn.

10. Cotton-Doubling Machine.—To twist two or more strands of yarn together for sewing thread, or for lace-weaving. The thread is

passed through water for double-twisting; if not wetted, it does not retain the twist. For twisting two threads together, the bobbins make 5,000 turns per minute. The motions are similar to those of the throstle. The rollers are two inches in diameter, covered with brass cast on, which is more durable than rolled tube- or sheet-brass. The two sides of the machine, having distinct change-wheels, may be set to spin threads of different thickness and twist.

11. Cotton-clearing Machine.—The purpose of this machine is, like that of the silk-cleaning machine, for removing irregularities, lumps, and knots from the doubled thread. The thread is wound off the bobbins from the doubling machine, and is passed through a steel clearer set to a gauge, upon bobbins on upright spindles driven by friction. The steel clearer, or double knife, is adjusted by a screw supported by a spring, which gradually yields to the pull of the thread, and stops the bobbin without breaking the thread, retaining it until the attendant removes the imperfection. The clearer-plate slowly rises and falls alternately, shifting the points of contact with the thread, to prevent local wear.

12. Hank-Winding Machine.—To wind thread from the dyed or bleached hanks of cotton, flax, or worsted, upon bobbins for balling, spooling, or warping, of four inches traverse. The machine is constructed partly for swifts and partly for barrels,—the first being sometimes preferred for soft cotton, and the second for glacé, or stiffened cotton. The bobbins are wound at a constant speed of thread, and for this purpose are hung on swings or hatches, and are turned by the superficial contact of the bobbin with polished iron pulleys, which causes the thread to wind at the same rate, whether the bobbin is empty or full. The pulleys are covered with cloth, and sometimes fluted, according to the description of thread. Should the thread break, the roller is lifted out of frictional contact by a self-acting pall, which is set at liberty.

13. Balling and Spooling Machines.—The machines have three heads for balling, and three heads for spooling, on one table; but they may be constructed of any convenient length. The spooling machines are of three kinds, and are much employed on account of the great extension of the use of sewing machines, which are worked with bobbins holding 700 to 1,000 yards of silk or cotton thread. The spooling machines are adapted to different sizes of thread, by means of brass change-pinions and steel guides. They are occasionally fitted with indices, to measure the length of thread; but, in general, the bulk of the spool is the only index.

14. Pirn-Winding Machine.—To wind silk or cotton on pirns for shuttles. The chief novelties are, that each spindle is worked independently

of the others, without interfering with their progress; and that the vertical movement of each spindle is effected by means of a ratchet-wheel, without resorting to the ordinary mode of forming the pirn by the pressure of cups and cones, which flatten and glaze the thread, particularly silk thread, injuring the colours and shades of the woven piece.

15. *Cubing Press*.—To make up small parcels of thread and knitting yarn, of various weights,

of $\frac{1}{4}$ lb., $\frac{1}{2}$ lb., or 1 lb.; which are tied up, whilst in the press, ready for sale.

16. *Bundling Press*.—Worked by hand or by power, to make up the large bundles of yarn for warps or sewings, weighing 5 lb., 6 lb., or 10 lb. each, which are tied up and labelled ready for sale.

A notice of other machinery exhibited by Messrs. Wren & Hopkinson, is to be found in the division of MACHINERY IN GENERAL.

SECTION V.

WEAVING MACHINERY.

CHAPTER I.

HISTORICAL ACCOUNT OF THE CALICO LOOM.*

Weaving is defined as "the interlacing together of two lines of threads at right angles to each other;" and the threads running from end to end of the piece are called the "warp," and those which cross from selvage to selvage—that is, from side to side of the fabric—the "weft." This is the definition of plain weaving. The process by which this interlacing is effected consists of three motions, which must be performed in succession. There is, first, the shedding of the web for the introduction of the shuttle with the weft shot; second, the throwing of the shuttle through the shed; and, third, the striking home of the shot. Now, all the improvements which mechanical skill has effected on the first rude contrivance by which these three motions were effected—by the "rude Indian" for centuries, and by the English hand-loom weaver up to 1738—are but expedients for facilitating these motions.

When John Kay, of Bury, in 1738, substituted the fly-shuttle for the hand-shuttle, by which the production of the hand-loom was trebled, his improvement was simply a facilitating of the second of the three essential motions in the process of weaving—"the throwing of the shuttle through the shed;" and the various "picking" motions applied to the power-loom, with the improvements which have been successively made in them, are but further expedients for performing with greater speed and facility the same primitive and fundamental motion. With the hand-loom, as improved by the application of the "flying shuttle," the weaver could throw a hundred shots per minute on a web a yard wide, while on broader work

the number would be reduced to about eighty; and this rate of shuttling was about three times greater than what had been previously practicable with the hand-shuttle.

The next great improvement effected in the hand-loom was the substitution of what is called the "friction pace" for the bore-staff previously used in tightening the web. It will be readily understood by those most ignorant of the art of weaving, that the cloth as woven is rolled on to a beam or roller in front of the loom, while the yarn which forms the warp is unrolled from a beam at the back of the loom. In the old hand-loom, the weaver had to stop shuttling after every two inches of cloth he wove, and "draw the bore;" and then he had to adjust the warp to the proper degree of tension by means of a ratchet and click. This interfered very much with his progress in weaving, and he was not always able so to adjust the ratchet and click as to secure a uniform tension of the warp. The "friction pace" remedied all this. This was an arrangement by which a weight, suspended to a rope passed two or three times round the end of the yarn-beam, converted the yarn-beam into a friction-roller. The amount of friction determined the degree of tension in the warp; and, by changing the weight, this could be either lessened or increased; but, when it was once adjusted to the fabric to be woven, uniformity was secured, and the weaver could "draw the bore" without disturbing the tension of his warp. Under this improved arrangement the weaver was exposed to less interruption in his shuttling, and he secured the advantage, so essential to the making of good cloth, of having his web kept at a uniform degree of tension. By a subsequent invention, applied to what was called the "Dandy loom," and which forms the principal peculiarity of that kind of loom, the weaver was saved the necessity of stopping to "draw the bore." A simple motion, connecting the lathe or slay with a ratchet fixed on the end of the cloth beam, caused the beam to take up the

* The Author is indebted for the contents of this chapter to an ably-written article on "Cotton-weaving and Lancashire Looms," published in *Macmillan's Magazine* for October, 1862.

cloth as it was woven. A similar motion is a feature in all power-looms; but, as applied to the hand-loom, although it was adopted as an improvement of considerable importance in the weaving of the coarser fabrics, it found little favour with the weavers of muslins and the finer kinds of cloth.

The invention of the power-loom is due to a doctor of divinity in England and a doctor of medicine in Scotland, both of whom seem to have conceived the idea about the same time, and to have worked on, unknown to each other, in developing their respective projects. The English inventor was Dr. Edmund Cartwright, a Church of England clergyman, who was incited to the rumination of a subject so foreign to the studies connected with his sacred calling by a tea-table conversation, while on a visit to a friend at Matlock, Derbyshire. Richard Arkwright, who had left Lancashire to avoid the fate of Hargreaves, had recently erected in the vicinity of the reverend doctor's temporary sojourn one of his large spinning factories; and the conversation turned on the great success which had been achieved in the application of machinery to spinning. Already the genius of Arkwright, Hargreaves, and Crompton had increased the production of yarn three hundred fold, and the question was asked,—Could not machinery be as successfully applied to weaving as to spinning? This turned the genius of the doctor in the direction indicated: he set himself to solve the suggested problem; and the result was a loom, theoretically capable of performing the three motions which are the essentials in weaving, but practically defective to an extent which rendered the invention useless. The doctor was not a weaver; he had not studied practically the nature of the material with which the weaver has to deal; and his loom lacked all those organs of sensation—if we may so speak—which the more perfect machine of modern times possesses, by which every slip or hitch in the working, caused by bad yarn or breakage, is either prevented or provided against, and which stop the loom when a “smash” is otherwise inevitable. The doctor could see the defects of his loom; but his want of practical knowledge denied him the power of remedying them, and the difficulties with which he long struggled proved to him insurmountable. It is surprising, however, on looking back, to see how near he came to the results of modern times.

Dr. Cartwright's first patent for a weaving machine is dated the 4th April, 1785, and of it he says:—“It is worked by mechanical force. The warp, instead of lying horizontal, as in the common loom, is in this machine (which may be made to hold any number of warps at pleasure) placed perpendicularly. The shuttle, instead of being thrown by hand, is thrown either by a spring, the vibration of a pendulum, the stroke of a hammer, or by the application of one of

the mechanical powers, according to the nature of the work and the distance the shuttle is required to be thrown; and, lastly, the web is taken up gradually as it is woven.” The number and variety of the mechanical expedients to which the reverend mechanic appeals for aid in throwing his shuttle, shows the crude and imperfect notions he had of what was requisite to produce the desired result. In practice, as we learn from the details of his invention, which have been preserved, Dr. Cartwright used springs for throwing the shuttle, and these springs were “connected with a cylinder placed beneath the machine,” which also gave motion to a lever, which reversed the shed of the warp. Successive improvements made in the machine, and patented in 1786, 1787, 1788, and 1792, did not bring it the length of practical utility; and after spending a fortune of between £30,000 and £40,000 in this and other mechanical projects, the doctor was rewarded with a Government grant of £10,000, in consideration of his inventions having led to the successful adaptation of machinery to weaving, which soon after came into general use.

Contemporaneous with these unsuccessful efforts to develop the power-loom in England, Dr. Jeffray, practising as a physician in Paisley, invented a loom which in principle was very similar to that of Dr. Cartwright. The leading feature in each was “that the shuttle and lathe were worked by the reaction of springs, and the power applied to them consisted in repressing them so as to bring them into a state fit for reacting at the proper time.” In one respect, the loom of the Scotch physician was superior to that of the English divine, and that was as to the means adopted for preventing the “smash” caused by the stoppage of the shuttle in the shed. A spring, which kept the shuttle from recoiling when it entered the shed, also supplied a motion which stopped the lathe when the shuttle was accidentally caught in its passage through the warp. But even this improvement did not entirely overcome the difficulty, and Dr. Jeffray's loom was never brought into practical use.

The man who first completed the improvements which made weaving by power practicable, was Mr. Robert Millar, a calico printer by trade, and the manager of a printfield near Glasgow. He patented, in 1796, an improvement called the “protector,” which stopped the loom altogether when the shuttle was prevented by any cause from accomplishing its passage from the one box to the other; and he substituted the direct action of the motive power for the springs formerly used in throwing the shuttle. He had also a motion for taking up the cloth as woven. These improvements, which were still further developed by Messrs. Radcliffe & Ross, Mr. Thomas Johnson, and Mr. H. Horrocks, all of Stockport, are features in all the power-looms which have since been made, and even in those models of

mechanical skill exhibited in the Western Annex, which present in so many respects such a striking contrast to the comparatively rude machinery for weaving which was in general use at the beginning of the present century. Millar's looms have been at work in Scotland until a comparatively recent period; and in the Great Exhibition of 1851, Mr. Joseph Harrison, of Blackburn, exhibited, in contrast with an improved loom of his own make, one of those antique and now almost unique machines. Of the contrast thus presented, it is well said in the *Encyclopædia Britannica*, "It needs no great culture of the eye to have noticed in exhibitions of machinery how often and how strikingly improvements in power and in efficiency are, at the same time, improvements in form and appearance." With the improved "power and efficiency" we have more to do than with the improved "form and appearance;" and what did that amount to? The loom of 1800 required the undivided attention of one operative to each warp, or, in special cases, five persons might tend six looms; but the loom of 1851 accomplished so much by itself, without the weaver's attention, and in spite of his carelessness, that two, and in many cases three, looms were worked by a single operative. On the loom of 1800 the most industrious operative could produce in a week of sixty hours no more than four pieces of printing cloth, 25 inches wide, 29 yards long, and with eleven picks or shots of weft in the quarter inch; whereas, with the loom of 1851 twenty-six pieces of the same kind of cloth could be produced with equal facility. The remuneration of the operative of 1800 was 2s. 9d. per piece for the description of cloth we have selected as an illustration, which made his weekly earnings 11s.; the price paid to the operative of 1851 was only about 6d. per piece, but this made his weekly earnings 13s.

The improvements of Mr. Millar, which gave to his loom the name of "wiper," from the motion of the shuttle being effected by eccentric wheels of this description, and those of Mr. Horrocks, which gave to his loom the name of "crank," from this agency being the means made use of by him for working the lathe, were soon combined; and they are to be found more or less improved and variously modified in all power-looms. But these improvements, great as they were, and demonstrating as they did the practicability of weaving by power, did not dispose of all the difficulties connected with the manufacture of cloth by the power-loom. One process to which we have not yet referred, necessary in the hand-loom, and still more in the power-loom, is "dressing"—the application of starch or size to the warp to give the yarn such a stiffness and consistency as may enable it to stand the strain to which it is subjected in the process of weaving. In the old hand-loom, the weaver "dressed" as much of the warp as was stretched from the back of the heddles or healds to the warp beam, which might be about a yard. He then worked

his cloth till the end of the dressed part came up to the heddles, when he again stopped and dressed a yard, and then resumed his weaving; and this process he had to repeat throughout the whole length of his web as every yard of warp was unrolled from the warp beam. It is evident that, however little this might be considered an obstruction or a hindrance in the case of hand-loom weaving, it was quite incompatible with weaving by power. It would not pay the weaver to stop his loom while he dressed a yard of warp; and the yarn would not stand the double strain of being dragged forward by the process of weaving, and pulled backward by the process of dressing. This difficulty rendered almost nugatory for a time the comparative perfection to which mechanical ingenuity had brought the process of weaving. But the inventive genius of those interested in the progress and extension of manufactures was soon turned, and that successfully, to the consideration of the means by which warps could be dressed or sized by power, and given out to the weaver in a state which would obviate the necessity for dressing. And there was more to stimulate the progress of invention in this direction than the desire to test the capabilities and obtain the full benefit of the power-loom. The great and rapid improvements which had been made in spinning machinery, by which the production of yarn had been increased three or four hundred fold, demanded means of consumption for the produce of the mule greatly beyond the capabilities of the old hand-loom and the new power-loom. The greatest desideratum towards this object was a machine for "dressing" by power, and this was soon supplied, and also proved by successive inventors, who gradually substituted "sizing" for "dressing" till the perfection had been attained which is now observable in the sizing machine known as the "slasher." By the use of these machines, the weaver is saved the necessity for dressing his warp yard by yard, as in the hand-loom, or in snatches and at irregular intervals, as in the power-loom, and being thus enabled to devote his whole attention to the process of weaving, makes greater progress in his work, and also makes better cloth. The invention of the sizing machine demonstrated for the first time, not the practicability of weaving by power, but the capabilities of the power-loom; and since then each successive improvement both in sizing machinery and in weaving machinery has increased its productiveness.

But the important advantages of sizing and weaving by power were not recognized all at once. Machines for both purposes had been brought to a comparative degree of perfection in 1805; but in 1813, eight years after, it is estimated that not more than 2,400 power-looms, with about 100 sizing machines, were in use in all parts of the country. From 1813 to 1820, the number of power-looms increased in a more rapid ratio, there being then upwards of 14,000 in use in England and Scotland. In 1830 the

number had increased to 60,000, and in 1833 to 100,000,—this latter figure showing the rate of increase to have been greatly accelerated during the three years from 1830 to 1833. But there was sufficient in the daily augmenting productive power of the loom to justify this great and rapid increase. The shirting, of which a good hand-loom weaver of full age and strength could weave only two pieces per week, could in 1823 be produced by two power-loom, attended by a youth of fifteen, at the rate of seven pieces per week, and in 1826 at the rate of twelve to fifteen pieces per week; while in 1833 a weaver of from fifteen to twenty years of age, with the assistance of a girl of twelve, could produce from four looms eighteen or twenty pieces per week.

The loom of 1862 is a striking contrast to that of 1833. In general appearance, the two machines may not be so dissimilar or present so great a contrast as that which is observable between the loom of 1800 and that of 1851; but in many points of detail the loom of 1862 has been so improved, by modifications and additions which may singly be comparatively unimportant, but in the aggregate amount to almost a revolution in its mode of operation as a machine for weaving, that the progress made during the last thirty years must be considered as important as that which resulted in the development of the loom of 1800 into that of 1851. The first improvement to be noticed is that beautiful expedient for stopping the loom when the weft thread breaks. It is evident that, when a weaver has three or four looms to attend, he cannot always notice on the instant the breakage of the weft thread; and should the loom continue working for even half a minute after the weft has broken (at the rate of, say, only 150 picks or shots per minute), the cloth-beam, by the motion which regulates its movements, will have taken up an inch to an inch and a half of the warp before it has received the weft necessary to make it into cloth. In such a case, the weaver would be under the necessity of "letting back" his web, so as to resume working at the exact spot where the weft thread broke, and this would prove a very great hindrance to him in the case we have supposed, of his having three or four looms to attend. But mechanical ingenuity having devised, and mechanical skill having successfully adapted to the power-loom, a peculiar motion, endued with sufficient sensibility to know when the weft thread breaks, and sufficient power to throw the loom out of gear, and stop, almost in an instant, all its rapid and complicated movements, the weaver is apprised of the breakage the moment it occurs, and is enabled to remedy the defect with the least possible loss of time. The first expedient for this purpose was the invention of John Ramsbottom and Richard Holt, of Todmorden, who, among other improvements in power-loom, patented by them in 1834, had a "contrivance for stopping the loom on the breaking of the

weft thread." It consisted of what the patentees called "hands and fingers,"—a sort of lever, so placed that the "fingers" rested on, and were supported by, the weft when the loom was working and all was going right, and fell down when the weft broke, and the support on which they rested was thus taken away. The effect of the "fingers" falling down was to disconnect a lever, which caused the next stroke of the "slay" (which contains the reed, and by the movement of which the weft is beaten up) to throw the driving-strap on to the loose pulley, and so stop the loom. The same patentees had also an improved contrivance for stopping the loom when the shuttle failed to reach the opposite box. These contrivances were improvements on the power-loom, but practically of no great value, except as paving the way for subsequent inventions. So far as regards the stoppage of the loom when the weft thread breaks, the "hand and fingers" were superseded by the motion invented and patented by Messrs. William Kenworthy & James Bullough, both of Blackburn, in 1841. The superiority of this latter appliance consists in the certainty and promptness with which the object in view, the stoppage of the loom for the preventing of damage, is secured. The patentees style their apparatus "the weft-watcher or detector;" and it well deserves the name, for with unerring certainty, on the breakage or absence of the weft thread, it instantaneously disengages the "taking-up" motion, and entirely stops the loom. The "detector" bears a general resemblance to the "hands and fingers," to the extent that the absence of the weft thread, releasing the lever over which it passes while the loom is working, is the "prime mover," if we may so speak, in the stopping of the loom; but the invention of 1841 has the decided advantage over that of 1834, in respect of the means by which the rising of a delicately constructed lever—so delicate that a thread fine as gossamer holds it in check—effects the almost instantaneous stoppage of the whole machinery of the loom.

The contrivance of Messrs. Kenworthy & Bullough has not been superseded by the ingenuity of any subsequent inventor, and all the improvements since effected in it are simply such as are owing to the superior skill and workmanship displayed by the different makers of looms.

To Mr. James Bullough is also due the credit of another invention, patented in 1842, for the prevention of damage and the stopping of the loom when the shuttle is caught in the shed. The contrivance for this purpose, patented in 1834, was not found to be always effective; but the importance of preventing the great damage to the web, which was inevitable when the slay, with the reed, beat up the shuttle instead of the weft shot, prompted and justified great efforts to remedy the evil. Mr. Bullough effected this desirable object by the invention of the "loose

reed," a contrivance by which the reed is "carried by a spring cap and swivels in the top rail" of the slay; and thus, when the shuttle is caught in the shed, the reed is forced back and acts upon levers, which stop the loom. This is an arrangement by which all uncertainty of action is done away with. The reed can never fail to be acted upon by the shuttle when it is in the shed; and there is a mechanical certainty that the movement of the reed will operate effectually on the levers connected with the stopping motion. We need only remark further, on the subject of the loose reed—which is applicable to all the lighter kinds of cloth, up to cloths having eighteen to twenty picks in the quarter inch—that it has enabled looms to be worked much quicker than was previously practicable. A 40-inch loom, for instance, which before the invention of the loose reed might be worked at the rate of 120 picks per minute, could afterwards be worked at 180 to 200 picks per minute, or at an increased speed of more than 50 per cent; and further improvements have since increased the practicable speed at which the same loom can be worked to about 230 picks per minute.

But the loose reed is not applicable to the weaving of heavy fabrics. The force with which the weft in the heavier class of goods requires to be beaten up is greater than could be applied with a slay fitted on the loose reed principle. The looms, therefore, for weaving cloths of a coarser quality than eighteen to twenty picks in the quarter inch, are all fitted with fast reeds, and it is left to an application termed a "stop-rod" to throw the loom out of gear when the shuttle is prevented, from any cause, from completing its course through the warp. This "stop-rod" is acted upon by the shuttle as it arrives at each end of the slay; and on its failing to arrive at either end, the "stop-rod" falls upon a moveable bracket, and instantly stops the loom. But this sudden stoppage of the loom, in the first application of the "stop-rod," was attended by a great shock, which caused damage, not only to the warp but to the loom itself; and as the "stop-rod" proved in practice very uncertain in its working, the mishaps it was intended to guard against were not always prevented. This led to another improvement of considerable importance, as applicable to fast reed looms,—an improvement which goes by the name of the "break," which was patented by Mr. John Sellers, of Burnley, in 1845, and by which the loom can be stopped instantaneously, whatever the speed at which it may be working, without the great shock to the machinery which the "stop-rod" produces when used without the "break." These several contrivances for stopping the loom, the most of them self-acting, requiring neither the presence nor the intervention of the weaver, effectually obviate the mischief which would otherwise be inevitable, and which, in the absence of these mechanical appliances, the most

watchful vigilance, supposing no more than one loom was under the care of each operative, would be powerless to prevent.

We must now notice the "taking-up" and the "letting-back" motions. We have already referred to the tedium of the process which compelled the hand-loom weaver, as every two inches of cloth were woven, to stop his loom and "draw the bore," and then adjust the warp to the proper degree of tension. Contrivances which, in view of more modern inventions, must be characterized as rude, superseded this method of winding the cloth on the beam, but they were far from securing uniformity in the make of the cloth, the quality of which was left largely dependent on the skill and care of the weaver. The importance of the "taking-up" motion in securing uniformity in the texture of the cloth will be apparent, if it is considered that every stroke of the slay (180, or it may be 250 per minute) brings the reed, by which the weft shot is beaten up, forward towards the cloth-beam to precisely the same spot; and this requires that the web be pulled on the cloth-beam the length of a pick (which may be the eightieth or the hundredth part of an inch) as each shot is beaten up, or 180 to 250 times per minute. These conditions, severe as they are, have been secured by the "taking-up" motion introduced by Messrs. Kenworthy & Bullough in 1841, and which has never yet been superseded. In this motion change-wheels are made use of, which secure, with the greatest nicety, that any given number of picks shall be put in each inch of the cloth. And this it secures with a mechanical accuracy which is in no way dependent on the weaver, who, either for the purpose of getting out more cloth, or from carelessness, might vary the number of shots per minute, and so produce a fabric which would be unsaleable on account of the irregularity of the texture.

Closely connected with the "taking-up" motion is the "letting-back" motion, a simple expedient, by which the web can be let back any number of picks which the loom may have worked after the breakage of the weft shot, that the beating up of the slay may be resumed at the exact spot it left off when the weft broke, and so the unseemly blemish of "gaws" in the cloth may be prevented.

Another important part of the power-loom is the "temple," which keeps the cloth stretched to the proper width, and which requires to be, like everything else connected with a loom driven by power, self-acting. In the hand-loom the temple was of wood, flat and hinged in the centre, with a button, which kept the hinge locked while the loom was at work. The length of the temple was the breadth of cloth, and a series of small spikes or needles at either end, caught in the selvage of the cloth, kept the web at the proper width. The shifting of the temple was a great hindrance to the weaver, as it required to be shifted every time the "bore" was

drawn, or after every two inches of cloth he wove. In the power-loom such an appliance would be perfectly useless. In the earliest efforts to construct a temple adapted to weaving by power, metallic discs were made use of, with small spikes or needles on the periphery, which caught in the selvage of the cloth, and thus kept it stretched at the required breadth. As the cloth was pulled forward on to the beam by the action of the "taking-up" motion, the discs revolved, and fresh spikes took the place of those which were thus disengaged from the selvage, so as to keep the cloth always stretched. This was the characteristic of the self-acting temple invented by that ingenious mechanic, Mr. James Smith, of Deanston, who had the spikes or teeth in his discs set at a slight angle, in a direction outwards from the fabric, so as to give them a better hold on the selvage. It was a very successful invention, and very extensively used, till superseded by the "roller temple," invented by Messrs. Kenworthy & Bullough, in 1841. This contrivance was "a small roller, covered with fine sand, emery, or other rough surface, revolving in a semi-circular trough or casing;" and the cloth passing under the roller, and between it and the casing, was transmitted of a parallel and uniform breadth to the cloth-beam. An improvement effected on this roller temple by the late Mr. John Railton, of Blackburn, was patented by him in 1842. In this improved temple, two or more rollers or bars are used, which are chased with a screw-thread, one half right-handed and the other left-handed, and also fluted, so as to present "a continuous surface of small points or pins." The cloth, being led over one roller and under the other, is kept distended tightly and transmitted over the breast-beam to the cloth roller. Another temple, combining the features of Mr. James Smith and Messrs. Kenworthy & Bullough's patents, was invented and patented in 1852 by Messrs. John Elce, of Manchester, and John Bond, of Burnley. In this invention "two or more rollers" are used, as in Messrs. Kenworthy & Bullough's, and they are covered with "rowels," and provided with guards and shells, so shaped "that the fabric to be distended in the loom is carried about half round each of the rollers." But the temple which has stood best the test of experience, and is now in most general use, is the "trough and roller temple" of Messrs. Kenworthy & Bullough.

These several improvements, with others due to the varying skill and ingenuity of the different makers, were to be seen in the looms exhibited in the Western Annex.

Note by the Author.—In the power-looms exhibited, as in nearly all, if not all, other looms, there are two shafts—the first and second,—the one below the other; of which the first is driven by the strap, and is called the first motion, from which all others in the loom are derived. The second shaft is called the second motion, and is in all cases driven from the first shaft at half

the speed, or number of revolutions, by means of spur gearing. By this disposition, the succession or cycle of actions is performed by the simplest means. The slay receives its reciprocating motion direct from the first shaft by means of a pair of cranks and connecting rods, or "arms;" whilst the changes of the shed and the throws of the shuttle are, with special exceptions, derived directly from the second shaft,—each change being timed once for every beat of the slay. The shuttle may be struck, or "picked," in either of two ways,—by the "overpick," or the "underpick;" so named after the situation of the propelling levers or "sticks," one at each end, which are started from the second shaft. In the overpick, the stick is fixed horizontally on the upper end of an upright shaft—the picking shaft,—which carries at its lower end a short lever, armed with a roller, which is struck by a cam on the second shaft once every turn of the shaft. The picking shaft is sharply turned on its bearings, and sways the picking stick horizontally over the slay, from one end of which the shuttle is propelled to the other end by the stick, through the medium of the picking strap and picker; and the picker is prevented from travelling too far by means of the stop strap. So soon as the cam clears the lever on the picking shaft, the latter is promptly drawn back to its first, or stationary, position, by means of a spring, through the medium of the heel-strap. Thus, a quick vibratory motion is given to the picking sticks, the movements of which are regulated by three leather straps to each, and the shuttle is driven alternately from one end of the slay to the other, across the web.

In the underpick motion, the picking stick, which carries a leather picker, is placed upright in the slay-frame, and is jointed to it at the lower side, near the base of the loom. It vibrates in, and is guided by a slot in the slay, and strikes the shuttle direct. The underpick, having fewer parts, more nearly direct connections, and vibrating on a fulcrum near the base, works more steadily than the overpick, and it requires less oiling. For the higher speeds, with plain and with light goods, the overpick is usually preferred, as it is light and nimble in its movements. For heavy work and lower speeds the underpick is usually preferred; there is less strapping and less oil used about the underpick.

CHAPTER II.

HISTORICAL ACCOUNT OF THE JACQUARD LOOM.*

Prior to the advent of the power-loom, the treddles were acted upon by the foot of the

* For the contents of this chapter the Author is indebted to a most able paper read at the Society of Arts, in February, 1860, on "Figure-weaving by Electricity," by Mr. P. Le Neve Foster, Secretary to the Society of Arts.

weaver, for raising the warp threads to form the shed for the passage of the shuttle. By a reverse action, the upper portion of the warp threads is lowered, and the lower portion raised, when the shuttle again passes and the interlacing is effected, which produces the desired fabric. Such is the operation of plain weaving, and from this it will be readily understood that if the warp threads are not raised or depressed in the alternate order of succession above described, there will no longer be produced a plain and uniform surface. For instance, in a twill the weft threads do not pass over and under the warp threads in regular alternate succession, but pass over one and under two, over one and under three, over one and under eight or ten, according to the kind of twill intended to be produced. The effect of this is to produce a kind of diagonal-ribbed appearance, either on the right or wrong side of the cloth, and a smooth and glossy effect on the other, according as the one thread is crossed above or below by the weft. In order to allow the weft to pass under two, three, four, or more threads at once, an arrangement is adopted, by means of which the weaver can, by the action of his foot on a series of treddles, raise and depress the warp, in groups, and in the order of succession required for the particular twill he desires. By various combinations among the treddles, he produces many varieties of movements, giving rise to the different kinds of twill. But when, in addition to, or instead of a twill, flowers, sprigs, spots, or any kind of figure, are required, then an amount of complexity arises which cannot be got over by any manageable number of treddles. The weft may pass over four and under one at one part of the width of the cloth, over two and under two at another, over one and under four at another, and so on, according to the part of the figure which may happen to occur at any particular part of the width of the cloth. The next weft threads would pass over or under in a different order, and hence the warp threads would have to be elevated or depressed in a continually varying order; and to effect this by increasing the number of treddles is obviously impossible; the loom could not contain them, nor the feet of the weaver move them. This difficulty was, however, got over by what was termed the draw-loom, in which strings were so arranged that a boy, by drawing them, could raise the requisite warp threads in readiness for the shuttle to pass. The principle on which this was done is simple enough, though the draw-loom itself, with its endless variety of strings, appears to a visitor a most incomprehensible piece of apparatus. The warp threads pass through eyes or loops in vertical strings, each thread having one string, and these strings are so grouped that the boy, by pulling a handle, draws up all those warp threads which are necessary to be raised for one particular shoot of the weft; when a different set of warp threads are required, he pulls a different

handle. It will thus be seen that, in order to produce any particular pattern, the arrangement of the strings and handles, and the order in which the latter are to be drawn, must have been previously formed with a view to that especial pattern. To effect this arrangement, which is termed "cording the loom," would employ a man several months, and then, of course, it could be used for the one particular pattern only. Endeavours were then made to render the loom more automatic, and thus get rid of the boy, and his possible mistakes of drawing the wrong handle. One of these, called the "draw-boy," is an ingenious arrangement of mechanism, which enables the weaver, by means of a treddle actuating a curved lever, to raise and depress the warp,—the lever travelling along a rack, so as to act on the different warps in succession. This arrangement was much used, whilst another extremely ingenious invention for the same purpose, the "automatic carpet loom," by Mr. Duncan, failed to come into use. In this loom the warp threads were raised or depressed by pins inserted in a rotating barrel, the pins being placed in their proper order of succession according to the pattern desired.

The object contemplated by Jacquard in the invention known by his name was to substitute an automatic mechanical action in lieu of the boy who actuated the warp threads by pulling the handles. At the upper part of the loom he arranged a series of perpendicular wires having a hook at each end, to the lower one of which cords communicating with the warp threads were attached. These wires he raised or lowered by means of a treddle, raising or lowering a frame called the "griff frame," which caught the hooks at the upper end of the wires. In order, however, to raise or lower these wires separately, or in groups, so as to form the required pattern, the following contrivance was adopted:—Each of the wires was made to pass through an eye formed in the middle of a horizontal needle, one end of which was acted on by a spring horizontally, so as to bring the needle back again after being pushed out of its place. Opposite to the ends of those horizontal needles he placed a hollow quadrangular prismatic box of metal pierced with as many holes as there were needles. This box, by the action of the same treadle, was at each stroke turned one-fourth round, and its face brought to strike against the ends of the needles, which, being exactly opposite the corresponding holes in the box, would pass into it and be in no way disturbed. To the face of the box, however, a perforated card was attached, the perforations of which corresponded accurately with some of the perforations in the box, whilst the unperforated portion of the card covered over the remaining holes. Hence it is clear that when the face of the box bearing the card is pressed against the ends of the needles, those will be driven back which are unable to enter the box;

the needles thus pressed back act on the vertical wires so as to remove the upper hooks from the reach of the rising and falling griff, which thus acts only on those wires the needles of which have passed into the holes of the box. It will thus be seen that by varying the holes in the cards, the wires may be raised or lowered accordingly, carrying with them the warp threads, so as to form the pattern. The cards must, of course, be carefully pierced in conformity with the desired pattern, and are joined together loosely at their edges, forming an endless chain, and are hung over the hollow prismatic box, which, turning on its axis, and having a reciprocating motion given to it by the weaver's foot, brings a fresh card forward at every stroke to be presented to the ends of the needles. The accompanying woodcut shows the principle on which the box and cards are arranged in connection with the needles and hooked wires. A few only of the needles and wires are shown in order to prevent confusion. The arrangement usually includes from 400 to 600 hooks, and sometimes, for very extended and special patterns, as many as 1,200 ;

FIG. 49.

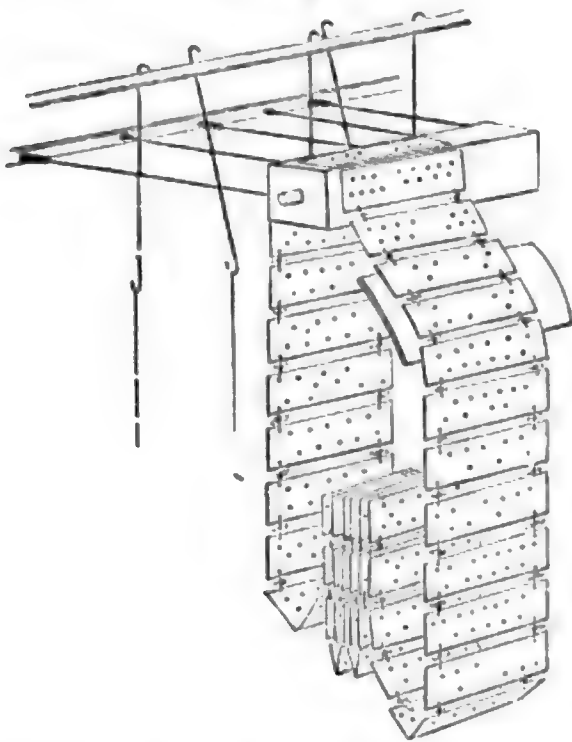


DIAGRAM to illustrate the action of the Jacquard Loom.

even a double 1,200 for some patterns. It will at once be perceived that the perforating of a series of cards so as to produce any given pattern is a task which requires some skill, labour, and time, varying, of course, according to the simplicity or complexity of the design (fig. 49).

For the purpose of transferring the design to the cards, it is in the first place prepared on paper by the designer, and is handed to another artist, who prepares from it what is termed the *mise en carte* drawing. For this purpose a paper ruled with lines crossing each other at right angles, and at a distance of about one-sixteenth

of an inch apart, is used, every square of which represents the intersection of a warp and weft thread. The design is transferred to this paper, which thus, on a greatly enlarged scale, represents the formation of the pattern as it should appear when worked in the fabric. This *mise en carte* drawing, which takes some considerable time and skill to prepare, is then put into the hands of the "reader," as he is termed, who takes it as his guide for perforating the corresponding cards, which is precisely the reverse operation to that by which the card produces the pattern. It is, in fact, a beginning at the other end of the process, and instead of the cards regulating the action of the needles, and through them governing the warp threads, the pattern being formed by hand, warp threads are made to actuate the needles, which thus form the punches used for perforating the cards. The reader forms in a frame a series of stout vertical cords to represent the warps, and with these he interlaces by hand, following the *mise en carte* drawing, a series of horizontal cords representing the weft, thus forming the design of large size loosely and in a very coarse material. As he proceeds in the formation of his pattern, he takes the warp threads which stand forward at each particular portion of the pattern, representing those which would actually be elevated in the loom, and carries them to the hooks of small rods, which represent what in the loom would be the hooked wires of the Jacquard, so that by suitable mechanical arrangements, when these warps are pulled, a number of small steel punches are driven into a metal plate pierced with as many holes as a card is made to contain. This metal plate, with its loose punches, is then placed on a table over the card, the whole put under pressure, and as the steel punches are somewhat longer than the thickness of the plate, they are forced through the card, which thus represents accurately the warp threads at that point of the pattern. The next series of warps in the pattern is dealt with in the same manner until the pattern is exhausted. The cards, previously numbered as they are punched, are strung together in their proper order, and thus form the means of producing the pattern in the fabric in the manner previously described. Many months, in some instances, are occupied in this process. It must be remembered, too, that the set of cards thus made serves for the one pattern only, and is useless for any other. Such being the case, it is not to be wondered at that men's minds should have been constantly engaged in endeavouring to devise means for simplifying or, if possible, getting rid entirely of this tedious and costly though very ingenious portion of the arrangement, and many contrivances, having this for their object or for the improvement, have appeared. In 1844, an arrangement was rewarded by the Society of Arts.

It was invented by Mr. W. C. Riding, and was called an index machine, and was a modification

of Duncan's barrel, with shifting pegs for changing the pattern. The pegs in Mr. Riding's apparatus acted in connection with the Jacquard wires. It was, however, applicable for small patterns only, and, though brought into use at the time, has not been extensively employed. A loom on this principle was exhibited at the Exhibition of 1851 by M. Moreau. Mr. Barlow also exhibited in 1851 a double loom, in which the cards were made to pass over two revolving prismatic boxes, by which means two fabrics of the same pattern were woven at once from the same set of cards. Subsequently to this, a very ingenious invention for getting rid entirely of the cards was brought out by Mr. E. Laforest, described in a paper read before the Institution of Civil Engineers. The object of this invention was to substitute a continuous band of perforated paper for the cards. Not only by this means was a great amount of weight and expense got rid of; but by means of a "reader," also the invention of Mr. Laforest, the bands of prepared paper, it is said, could be cut at the rate of 3,000 per hour, instead of the slow and tedious process of producing the cards. This arrangement, though ingenious, has not come into operation, partly from the minuteness and crowding of many of its parts rendering it liable to get out of order, and chiefly because of the expansion and contraction of the paper in varying states of the weather.

The Jacquard loom did not come generally into use in this country till about thirty years ago, and now it has completely superseded every other description of apparatus for producing figured work in the loom. It is applied to the power-loom, and has been adapted to carpet-weaving and lace-making. Numerous improvements in detail have from time to time been made, among which, and in particular, the invention of Mr. Bennet Woodcroft deserves notice, namely, an arrangement by which, while one portion of the warp threads is elevated, the other is not merely left at rest, but depressed. This has been found of essential service in certain classes of weaving.*

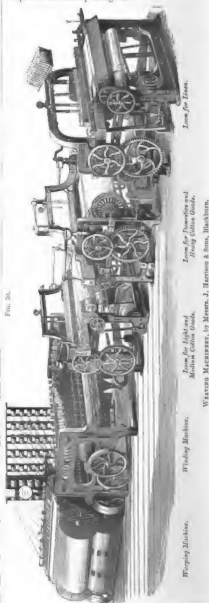
CHAPTER III.

MACHINERY EXHIBITED BY MESSRS. J. HARRISON AND SONS, BLACKBURN.

Messrs. Harrison exhibited a complete series of machinery for treating the yarn, preparatory to and inclusive of the process of weaving into cloth,—comprising the operations

* A work recently published (June, 1863), by Mr. Bennet Woodcroft—"Brief Biographies of Inventors of Machines for the Manufacture of Textile Fabrics,"—contains many interesting particulars of the proceedings of early inventors of spinning and weaving machinery.

of winding, warping, sizing, and weaving cotton and linen. They were of excellent workmanship, and creditably designed.



Loom for Linen.

Loom for Powerlooms and Heavy Cotton Goods.

Loom for Light and Medium Cotton Goods.

WEAVING MACHINERY, by Messrs. J. Harrison & Sons, Blackburn.

Winding Machine.

Warping Machine.

1. *Winding Machine*.—This machine is for winding yarn from the cop on spools or bobbins,

called "warper's bobbins," for the purpose of warping or beaming the yarn. The threads are unwound from the cops or spools, and directed through "feathered guides," or minute slits in thin plates, sufficiently wide to pass the thread so long as it is of the proper thickness, but to intercept the thicker parts. The slits are feathered, or branched with blind ends, to prevent the threads being slipped upwards out of the slit by an indolent attendant, when a thick part is seen to approach the guide. The threads are also passed through brushes, which intercept dirt, and lay the fibres. The bobbins are filled regularly and uniformly. There is an arrangement for winding cotton or linen yarn from throstle-bobbins on to warper's bobbins. The spindles are adjustable to a level, by means of set-screws below the spindle-rails, after the displacement to which they are subjected by the operation in putting on the bobbins. The vertical movement for shaping the bobbin is derived from heart-shaped cams on a shaft, by means of which the bobbins can be filled up in any form. The winding machine was exhibited with 32 spindles, which wind 400 lb. of forties twist in a week. It may be made for any number up to 450 or 500 spindles (fig. 50).

2. Warping Machine.—The next operation is to wind the yarn from the warper's bobbins on beams, by means of the warping machine. The chief novelty in this machine consists in the method of supporting the rollers on centre points, on Knowles & Blackburn's system, to revolve easily, without undue tension on the yarn, and to obviate breakages. It is also supplied with a letting-back motion, whereby, when a thread is broken, the roller can be reversed, and the broken end discovered, to be reunited. By a self-acting motion, the machine is stopped when the required length of warp is wound on the beam. The drum on which the beam revolves is made to be contracted or extended lengthwise, according to the width of beam required. This machine is capable of working Surat and other low cottons, and generally more delicate yarns than the ordinary machine. It is also applicable for winding silk (fig. 50).

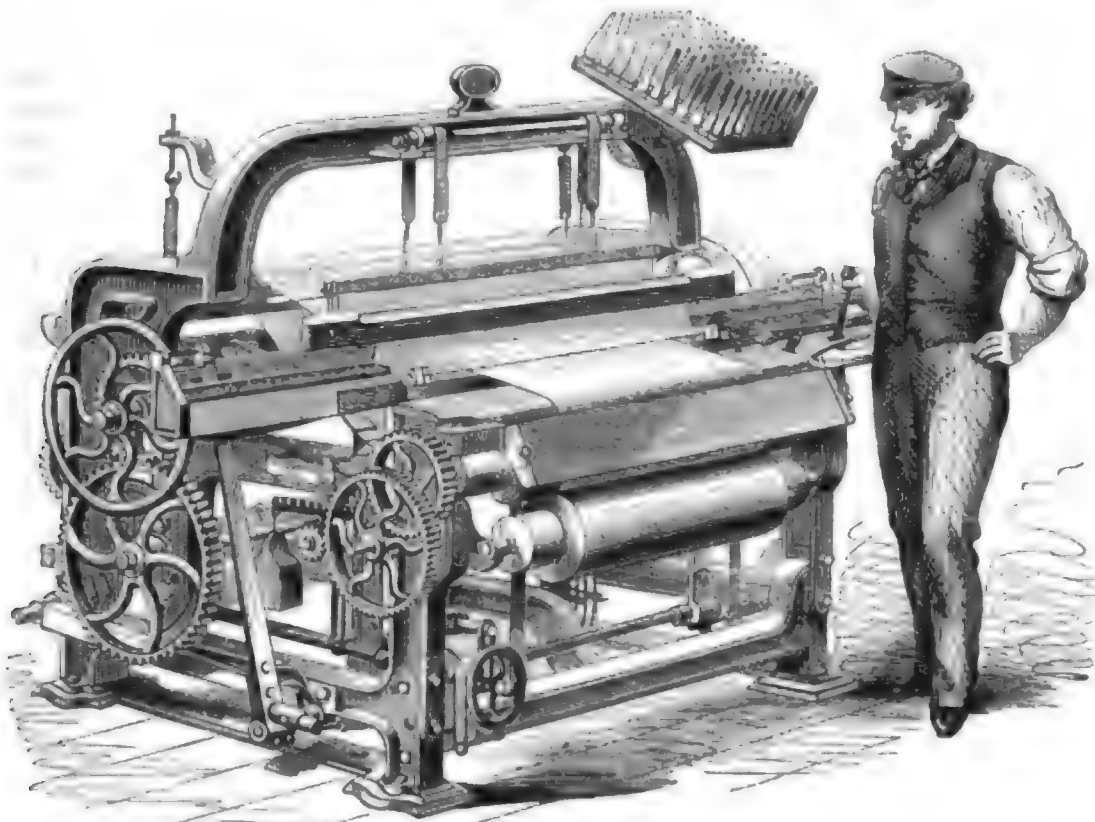
3. Sizing Machine.—The function of this machine, commonly called the "slasher," is to size or dress the warp from the warper's beams, to prepare it for weaving. The yarn is brought from the warper's beams, through boiling size, and over drying cylinders, and is ultimately wound on the weaver's beam. The warper's beams, usually six in number, sometimes eight, are hung on a creel or stand, and set accurately in line by means of adjusting screws. The boiling size is contained in a box lined with copper, to prevent oxidation, and the threads from the several beams are all run together into the sizing-box, and pass under the immersion or sizing roller, which is of copper. The yarn then

ascends, and is passed between two pairs of squeezing rollers, over the size-box, of which the upper rollers are covered with flannel, which preserves the round form of the thread; whilst at the same time it presses the size into the thread, and so strengthens it considerably. The quantity of size required to be put into the thread can be, in a great measure, regulated by the quantity of flannel put on the rollers. The under rollers—one of which is of copper, cast in a piece, bored out, and expanded on a mandril,—are hooped at the ends with brass, and run on brass pulleys, giving a smooth motion, and preserving the ends of the rollers from injury by the size. The sizing roller is lowered and retained by gearing; the copper roller, being seamless, is free from the objections to brazed rollers, in which the seam is acted on by the acid matter in the size. The yarn is now passed over two large drying cylinders of copper, or of sheet-iron, which are heated by steam of 10 lb. or 12 lb. pressure, having a temperature of 240 degrees Fahrenheit. The supply of steam, and consequently of heat, is regulated by means of a throttle-valve; and, when the machine is stopped, the steam is shut off altogether by the same handle that stops the machine, which is an important provision to prevent accidental overheating of the yarn. The cylinders are made with manholes in one end, covered with steam-tight lids, and there is provision for the escape of condensed steam from the cylinders through the axle. There are also syphon-boxes for the purpose of condensing the steam as it comes from the drying cylinder, with provision for turning the waste steam direct into the size-box, to boil the size when needful. There is also a diminishing or reducing valve, to regulate the supply of steam to the cylinder, and to keep it at a uniform pressure and temperature therein. From the drying cylinders, the yarn is led by means of guide rollers over and around a fan, which directs a strong current of air over the yarn, to complete the drying of it; thence it passes over a larger roller driven from the last pair of sizing rollers, with an adjustable friction-coupling at one end, to regulate the tension on the yarn during the drying process. The yarn is finally wound on the weaver's beam, which is driven by means of a pair of conical drums with a shifting belt, to maintain a uniform winding speed, as the roll enlarges, and to equalize the drag on the yarn. By means of this improved machine, 100,000 yards of warp may be dressed per week, sufficient to supply 300 looms. Surat and American cotton may be worked equally well, as the degree of tension may be adapted to the quality of yarn. The sizing machine exhibited by the same constructors in 1851 was adapted for supplying only 120 looms; whilst the machines previously in use could supply only 20 looms. Messrs. Harrison have estimated that the quantity of production through the sizing machine, which

heavy linens. It is fitted with Collier's positive motion for letting off, and with a positive taking-up motion, the two movements being in connection and working in concert, so that the warp is delivered from the yarn-beam at the same rate when nearly empty as when full. The object of this letting-off motion is to produce a uniform tension throughout the warp without the aid of the workman. It is fitted with the trough-and-roller temple. Two vibrating shells are applied at the back of the loom, the lower shell regulating the tension on the yarn, the upper one giving ease to the

treddles in changing the shed. Linen, though strong, is comparatively a brittle thread, more liable to break than cotton, and it needs more careful treatment. The shed is made by means of two treddles, worked by two cams on the second shaft, with four healds coupled two and two. The loom is fitted with an underpick motion, usually making 150 to 160 picks per minute; the motion is derived from the second shaft, by a lever on each end, which revolves and strikes a stud on a horizontal wooden lever, connected with and moving the picking stick with an elastic touch (figs. 50 and 52).

FIG. 52.



LINEN LOOM, by Messrs. J. Harrison & Sons.

CHAPTER IV.

MACHINERY EXHIBITED BY MESSRS. W. DICKINSON AND SONS, BLACKBURN.

Messrs. Dickinson exhibited a sizing machine and three power-loom.

1. *Sizing Machine*.—This machine was similar to that of Messrs. Harrison & Sons, and was capable of supplying warps for 300 looms.

2. *Calico Loom, with Loose Reed*.—This was a plain loom of ordinary construction, with the overpick motion which was invented by Mr. Dickinson in the year 1827. This loom was noted for the crank-arms, on Mr. W. E. Taylor's principle, which were applied to it. The "crank-arm" is what a steam-engineer would call a connecting rod, connecting the crank on the

first shaft to the back of the slay. The speciality of this crank-arm is that it is very short, being reduced from 12 inches, the usual length, to 4 inches long, about one and a half times the length of the crank; and to those who are familiar with the motion of the piston of a steam-engine, it must be obvious that whilst the crank revolves at a uniform velocity, the slay will be promptly moved up to the web and withdrawn from it during one-half of a turn of the crank, and will be retained nearly stationary during the second half turn, causing thereby a "dwell," during which time the shed may remain open for the passage of the shuttle, and for a longer period, at a given speed of loom, than with a crank-arm of the usual length. The principle of this crank-arm is good, but it must be worked in moderation. The loom may, no doubt, with this crank-arm be worked at a higher speed, whilst the shuttle travels at a lower speed than with the common arm; but it is obvious that

the strain on the slay and its connections, being extremely irregular, must be excessive at the higher speeds. A clearer shed is obtained for the shuttle, for which a saving of half the breakages of yarn is claimed. Be that as it may, it is obvious that the picking motion may be worked with greater ease, and with a saving of power, at the same speed. Mr. Wm. McNaught, of Manchester, having tested, by means of a differential dynamometer, the comparative power required to work two looms of the same construction, and working at the same speed—about 230 picks per minute,—weaving the same breadth and quality of cloth; he found that one of the looms having Taylor's crank-arms attached required from twenty to twenty-five per cent. less power to work it than the other, with an ordinary crank-arm. If this result be adopted, it would show that the proportion of power required to throw the shuttle is greater than that required to work the slay; and that the saving by reducing the speed of the shuttle was greater than the increase of power required to work the slay with an unequal movement. The loom frequently worked at 350 picks per minute; and at 420 picks as the maximum. The weft threads were frequently broken. Messrs. Dickinson have applied Taylor's crank-arm to all the looms in their own mills,—about 1,000. Though the principle of the short crank-arm is not novel, there is no doubt that the revival of it in the Western Annex has redirected general attention to its capabilities. Whether it will ultimately lead to a general increase of speed in looms is a question for further experience, but there appears to be no doubt that for the same speeds, Taylor's crank-arm may be advantageously substituted for the ordinary arm. It is also specially adapted for wide heavy looms, where a "dwell" is desirable, for a long throw of the shuttle.

This loom has four healds in two pairs, worked by two cams or tappets on the second shaft, acting on two treddles of ash. The yarn is strained by a rod across the back of the loom, which keeps it in tension, and eases it for the shed, being for this purpose vibrated by an eccentric motion from the first shaft. The taking-up beam is a hollow iron casting covered with laths and emery, laid on with glue, which will answer for dry warps, but not for wet. A brake-wheel is applied to the crank-shaft, to which a self-acting brake is applied when the loom is thrown out of gear.

3. Fancy Loom.—This loom is adapted for weaving dress pieces,—as checks, gingham, diapers, velvets, and linsey-wolseys. It is constructed similarly to the first loom already described, but has in addition a three-shuttle drop-box for three shuttles, with eleven healds and the "dobby" patented by Mr. W. Bullough attached. Provision is thus made for changing the substance of the web and working it out to

a pattern,—first, by means of the shuttles, which carry three hobbins of threads of different texture and colour, to introduce three varieties of thread into the weft; second, to make several changes in the disposition of the warp for making the shed, by means of the healds, which control the warp threads. As the changes are necessarily irregular in time and in sequence, they are provided for by special appliances. In the first place, the changes of the weft are made by raising or lowering the shuttle-box, which holds three shuttles deep, so as to bring the proper shuttle to the level of the picker, to be thrown across the warp and back again. The same thread may be required to be thrown several times successively, and the shuttle-box remains stationary till the next change of thread is required. By means of a self-acting motion derived from the dobby frame, an endless chain, with links of three different depths, is shifted round, one link at the right time, upon an axis; and a lever, which is connected with the drop-box, bearing upon the particular link of the chain which is uppermost by means of a friction-roller, is at the same time raised or lowered according to the depth of the next link which is drawn under it; the drop-box is also raised or lowered by the lever, and so makes the change of shuttle. The number of links in the chain is therefore equal to the number of changes in the weft thread requisite to complete the pattern, which of course repeats itself.

Again, to make the consecutive changes in the warp threads for the shed, the healds, eleven in number, which control the warp threads, are suspended by the medium of wires and levers from the dobby frame; the changes are made similarly to those of the Jacquard, by the instrumentality of two series of "lags," or cross pieces of wood, attached to and travelling with two endless bands, numbering, in this instance, 180 lags on each band. There are eleven lines of pegs fixed on the lags, with certain vacancies, and where there are no pegs there are holes in the lags. As each lag is presented successively to the wires from which the levers or jacks and the healds are suspended, the pegs which are present knock back the wires opposed to them; and the wires which are not knocked back—namely, those which are opposed to the blanks—are carried up to form the shed. The lags are changed by means of a ratchet motion worked by a crank on the second shaft, which turns a pin-wheel on the axis of the "cylinder" on which the lag bands are shifted.

Jacks for the taking-up motion are worked by the dobby frame alongside the heald-jacks. The tension-roller vibrates in front, just over the taking-up rollers, to equalize the tension on the warp yarns, instead of behind, as is usual.

This loom weaves three yards per hour. The combination of the simple direct-acting dobby with the chain motion of the deep boxes, affords facilities for weaving any length of pattern, and

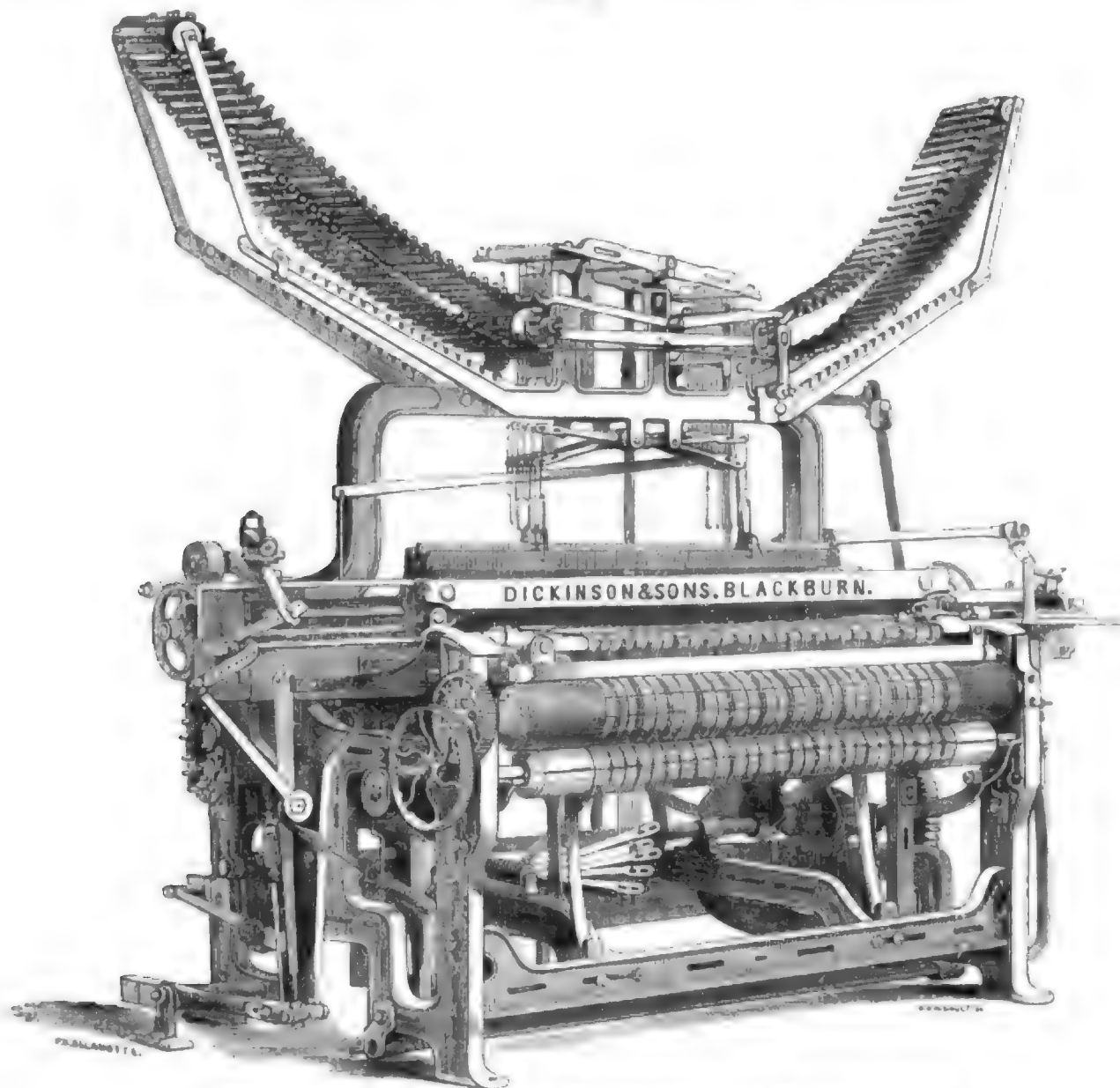
any change can be made in the design with ease (fig. 53).

4. *Fancy Loom, with Single Shuttle.*—This loom is constructed in all respects like the fore-

going fancy loom, except that it has but one shuttle. It is adapted for weaving Indian scarfs. It produces about four yards per hour.

The fancy looms exhibited by Messrs. Dickinson were effective and creditable machines.

FIG. 53.



FANCY LOOM, for weaving Dress pieces, by Messrs. W. Dickinson & Sons, Blackburn.

CHAPTER V.

MACHINERY EXHIBITED BY MESSRS. J. DUGDALE AND SONS, BLACKBURN.

Messrs. Dugdale & Sons exhibited a winding machine and two looms.

1. *Winding Machine.*—This machine is designed for winding twist from the cop on to the warper's bobbins. It makes a barrel-shaped bobbin, with the mangle-wheel motion. A pinion on the axis of the mangle-wheel gears into one end of a rack-bar, which thus derives an alternate horizontal motion. The other end of the rack-bar gears with an eccentric toothed pinion, which reciprocates with a rotation alternately

fast and slow. This varying velocity is communicated by an ordinary pinion on the same shaft to an upright rack, which guides the thread on the bobbin,—slowly over the middle of the bobbin, and more quickly over the ends, resulting in a barrel shape.

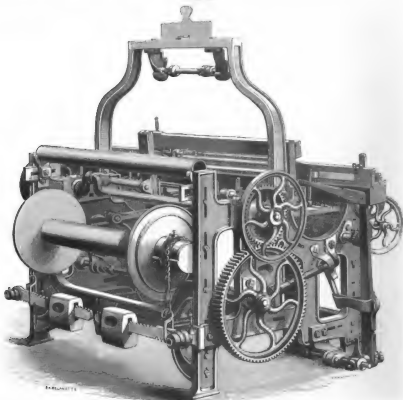
The threads pass through plain slits in the steel guide-plates fixed to the traverse-rail, to pass the thread freely, but to intercept and break off knots. The guide-plates are continuous, to prevent attendants slipping the threads out of the slits and over the ends of the plates, an object which is provided for in Messrs. Harrison's winding machine by the "feathered guide." The elevation of the spindles, for bobbins of unequal sizes, is adjusted by means of set screws. When the cops are nearly all run

off, they are placed on the "jigger," with the spindles in a horizontal position, to complete the unwinding with facility. The brush for cleaning the thread is in three lines, spaced a little apart, and is thus more easily got at to be cleaned than when in one continuous breadth. This machine is exhibited with 96 spindles, in two rows.

2. *Fast-reel Loom*.—This loom is adapted to weave heavy domestics, twilled and plain goods, drills, and tweeds. It was weaving four-leaved

twill, having four bealds, connected to four treddles worked by tappets or cams. The tappet-shaft for four-leaved twill is distinct from and driven by the second shaft—by gearing, making one turn for two of this shaft, or one for one of the first shaft,—the tappets being timed to strike alternately. The loom has an overpick, and makes 220 picks per minute. A "picker-preserver" is attached to the shuttle-box, consisting of a leather strap, which slides on the fly-spindle, to receive and stop the shuttle, one end of it being attached to an elastic lath of wood fastened

FIG. 54.



CASICO LOOM, by Messrs. Platt Brothers & Co., Oldham.

to the shuttle-box. By means of a brake-wheel on the first shaft, the loom can be instantly stopped when the band is thrown off.

3. *Loose-reel Loom*.—This loom is adapted for fine goods. It has an overpick, and makes 250 to 260 picks per minute. The chief novelty is the shedding motion, by which the bealds are pulled straight up and down, being strung up over upper and lower rollers. On the shaft of

the lower rollers a toothed pinion is fixed, and worked by a horizontal rack with a reciprocating motion derived from a cam on the second shaft. By the straight vertical movement of the bealds, compared with the angular action of the treddles, there is less rubbing of the reeds upon the warp threads, and the size is better retained, which yields a better cover or nap on the cloth. There is another refinement about this loom, the object of which is further to improve the nap by throw-

ing up the fibres of the weft,—the warp shed closing earlier than usual, and holding the weft closer between the folds of the shed as it is being driven up by the slay.

4. *Contracting Collars*.—For slubbing, roving, and other spindles, in spinning machinery. There is an arrangement for contracting the collar by a slight turn of a key, when it or the spindle becomes worn, to make the collar a good fit, and to steady the spindle.

CHAPTER VI.

SUNDRY PLAIN CALICO LOOMS.

Messrs. Booth & Chambers, of Bury, exhibited a plain calico loom, with loose reed and underpick, in which various novelties are claimed. The second shaft, from which the picking motion is derived, is driven by the first shaft, through a carrier-wheel. The pick is performed, on Todd's principle, by a hammer on each end of the second shaft, which strikes an intermediate horizontal lever, which pulls over the picking-stick, to which it is connected by a strap. The healds are stretched by endless bands passing over pulleys on the upper and lower heald-shafts, and are worked by means of a pinion on the lower heald-shaft, driven by a reciprocating rack, worked from the second shaft by means of a pair of spur-wheels and a crank. Thus, the healds move straight up and down. The letting-off motion is actuated by the blow of the reed on the cloth, and is worked from the slay-sword by means of a ratchet-wheel, and a worm gearing into a worm-wheel on the warp-beam, as in Messrs. Harrison's linen loom: this method was patented by Mr. Collier, of Halifax, about twelve years ago, and originated in a patent by Mr. T. Melladine, of Oldham, in 1834. The taking-up motion is of that class which is regulated by the increasing diameter of the cloth-beam, in place of the usual ratchet-wheel motion. The motion is given by a lever carrying wedges acting against the circumference of a plain wheel or disc, the motion of the lever being less as the cloth-beam increases. Thus the emery roller is dispensed with, and the cloth is secured at every pick. These motions are not new.

There is a vibrating rail parallel with the yarn-beam, in which the yarn-beam rests in such a manner as to do away with the difference of leverage arising from a full and an empty beam, and thus dispensing with the friction levers, chains, and weights. The loom made 230 picks per minute, but the usual speed is 200 to 220 picks.

Messrs. Platt Brothers & Co. exhibited a plain calico loom, with underpick. It was weaving cassinet, and made 170 picks per

minute. It picks from the first or crank shaft, by means of a hammer at each end of the shaft. The picking tongues are hinged on the picking rods, and are raised by a lever at each end, worked by a cam on the second shaft every alternate turn of the shaft, to clear the hammer at one end, whilst the pick is given by the hammer at the other end. This pick is simple, and may be easily repaired; but, like that of the loom just described, it works harshly. There are six healds, worked by six jacks, which are connected by steel ribands, instead of the usual cords, to the treddles. The circuit is completed by six jacks below. The picking stick recoils on a spiral spring at the heel, instead of the ordinary heel-strap. A reed is hung behind the healds to intercept dirt and prevent breakages.

A similar loom, picking from the second shaft, is shown in fig. 54.

CHAPTER VII.

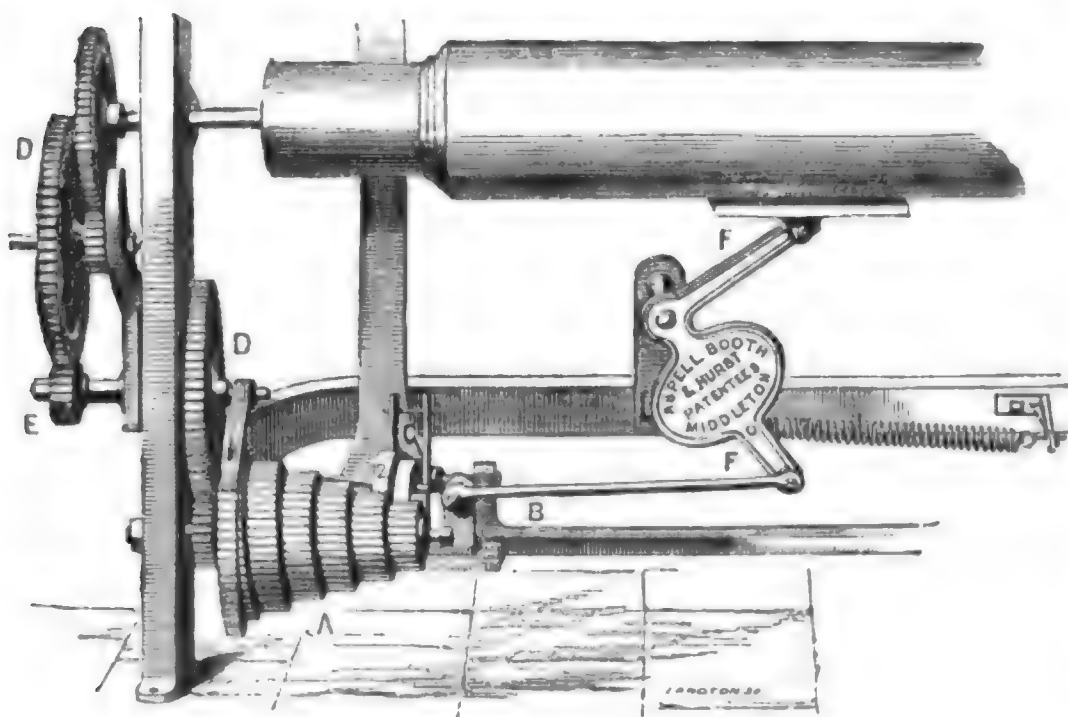
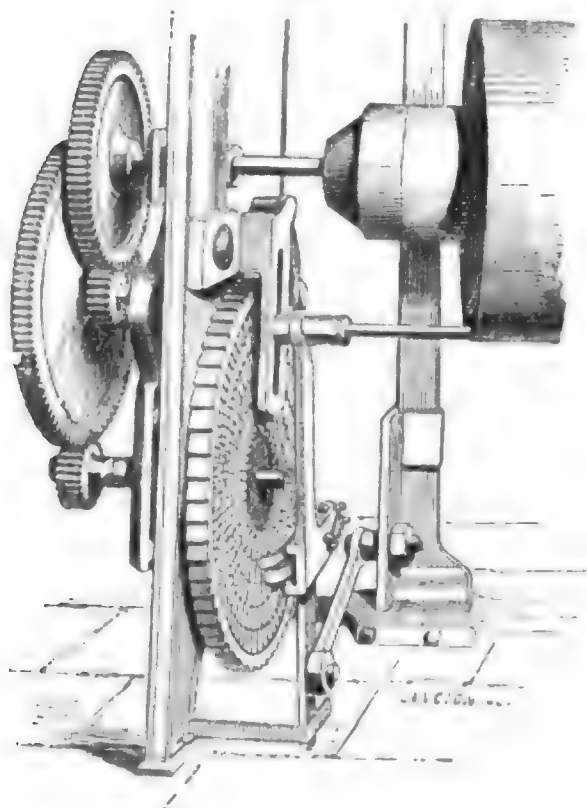
MACHINES EXHIBITED BY MESSRS. TUER AND HALL (NOW MR. ROBERT HALL), BURY.

Mr. Hall exhibited three looms and a shearing machine.

1. *Heavy Fustian and Nankeen Loom*.—This loom is adapted for weaving linens, bed-ticks, velvets, velveteens, cords, moleskins, Jacquard work, and woollen goods. This loom has one shuttle with underpick from the crank-shaft or first motion, which was patented twenty years ago by Luke Smith. It was weaving velveteen with six shafts and six tappet-wheels on one axle,—an arrangement invented forty years ago by Luke Smith, and now in common use. The tappet wheels make the changes of shed, and consequently are driven from the crank-shaft to make one revolution for two of the first motion. The tappets or levers which rise and fall over the tappet-wheels, are connected with the outer ends of six jacks above and six below, the inner ends being connected with the healds, and drawing them up and down to form the shed. The loom is applicable, by a change of tappets at the end, for weaving any variety of cloth. The mode of letting off the yarn is by a chain passed round a flange on each end of the yarn-beam, and held tight by means of weighted levers. The taking-up motion is differential, not positive. It is worked by the forward blows of the lathe or slay on the cloth, by the agency of a weight which is previously lifted, by intermediate connections, at each backward movement of the lathe, sufficiently to shift a ratchet one-tooth in a ratchet-wheel. When the lathe strikes forward, the web is momentarily slackened; the weight, no longer sustained, takes up the slack by pulling over the ratchet-wheel, on the axis of which a worm is keyed. The worm gears with a toothed wheel on the end of the cloth-beam and turns it round,

taking up the loose cloth,—a very small portion at a time of course, say $\frac{1}{400}$ inch, equal to a thread at a time. This method of taking-up, when properly attended to and adapted to the nature of the material in the loom, is the best

FIGS. 55.



POSITIVE TAKING-UP MOTION, by Messrs. J. Aspell & Co., Middleton; with one Plain Beam. (Two Forms.)

motion for very heavy cloth, especially for cloth woven with uneven weft. During the Exhibition, one piece of cloth was woven in this loom with Aspell's positive taking-up motion, in which a spiral ratchet-wheel is employed of in-

creasing diameter, to which a pair of clicks are applied, and regularly traversed on the increasing radius of the spiral ratchet as the cloth beam increases in diameter, by means of an under-presser acting through a bell-crank. This motion was good for light work; for heavy work the gearing was found too light (figs. 55). The temples were novel; they consisted of five rollers, two plain and three spiked, to seize and retain the heavy cloth. The loom makes 180 picks per minute.

2. Gingham or Fancy Loom.—This loom is suitable for weaving checks, plaids, diapers, drills, quiltings, waistcoatings, diamonds, and satins. It is made with a three-shuttle drop-box at each end, with underpick, to take the "oddpick" or "pick and pick;" that is to say, to shoot one, two, or three shuttles in succession from one end of the lathe, giving a succession of single threads where required to work out the pattern. In Messrs. Dickinson's dobby loom, which has been described, the picking is double; that is to say, a shuttle, having been thrown at one pick, must be returned next pick, and two or another even number of threads from the same shuttle must be shot. The loom has eight shafts or jacks hung above and below the healds, as in the fustian loom, and connected similarly; but, instead of the circular tappet-frames for working the shed, there is a set of eight levers, the ends of which are connected severally to the jacks above and below to com-

plete the circuit with the healds. The lifting of the levers to form the shed is performed by an endless chain passing over a four-sided prism or "barrel" at the right hand side of the loom, driven by spur gear from the crank-shaft, and so placed under the levers as to lift them near to their fulcrum bearings. The chain, being interposed between the prism and the levers, and advanced one link at a time for each pick, is formed

with links of changing thickness to raise the levers at proper intervals, so as to lower such healds as are required to form the under side of the shed; one or more of the levers which have been elevated being permitted by the

next link of the chain, which is comparatively shallow, to fall by their own weight, and lift the healds proper for the upper part of the shed for the following pick. There were 68 links in the chain, representing 68 picks to complete the pattern. The side levers must be sufficiently heavy to be capable, by their own weight, of forcing up the healds with the yarn that is required to be lifted, and it must be hard work for the crank-shaft to lift, particularly for heavy upper sheds.

It is obvious that the method of the tappet-wheels, though excellent for the limited number of changes of shed required in the fustian loom, would not be applicable for working such a number of changes of shed as are here provided for in the endless chain:—ten changes by the tappet-wheels, and sixty-eight changes by the chain. The chain is, in effect, a tappet-chain, to replace which an equivalent tappet-wheel would require to be 9 feet in diameter.

The drop-box is raised and lowered for the changes of the shuttles by means of a chain (Diggle's patent) working over a prism at the left-hand side of the loom, having the same number of links as the tappet-chain,—as many links as there are picks to form the pattern. The links are of three different thicknesses, and act like the tappet-chain in raising or letting down at the proper time for changing the shuttle, a lever which bears upon them with a friction-roller, and is connected at the overhanging extremity to the frame which carries the drop-box. The prism has eight sides, and carries the chain one link forward for each pick; it is turned by means of a star-wheel on the same shaft with eight notches, which is moved by pins on a carrier spur-wheel driven by a pinion on the crank-shaft.

To work the picks, odd and even—that is to say, to throw the proper shuttle from the end of the slay at which it stands, and if necessary, to put out of gear the picking motion at the other end till a pick is required from that end—a third chain of sixty-eight links is applied at the left-hand side, working over a prism on the same shaft as the prism for the drop-box chain, with links of different sizes, and a lever overhead, connected to the picking shaft at each end. To put the picking shaft out of gear, it is slid on end sufficiently to remove the picking finger out of the way of the picking hammer on the second shaft, when the picking stick remains at rest. By shifting it back to its first position, the picking finger is exposed to the stroke of the hammer, and the picking stick throws the shuttle. This, the picking chain, is the invention of Mr. Mark Smith, who patented it in 1851.

The loom made 130 picks per minute, and was fitted with the ordinary taking-up motion. A guard is fixed to the slay-cap to prevent the shuttles flying out, which they are liable to do when worn round on the under side, subject to the angular stroke of the underpick. The loom

was originally fitted with Briggs & Fearnley's positive take-up motion, which was subsequently removed, and replaced by the ordinary take-up motion.

The piece woven by this loom in the Western Annex had three shuttles with three different threads:—a thick black thread, a thin black thread, and a violet silk thread. Whilst the silk is being thrown the taking-up motion is suspended, as the thread is so thin that the silk weft would lie wide if the take-up were in action. The take-up action is provided for by an additional jack, which is worked by the tappet-chain, and by suitable connections lifts the pall out of gear with the ratchet-wheel on the take-up motion. This class of loom is used chiefly in weaving "reps," where thick and small threads require to be thrown alternately.

3. Tapestry Carpet Loom.—This loom is suited for weaving pile, velvet, or Brussels carpet, with or without the Jacquard. It may also be used for weaving Utrecht velvet for the lining of carriages and omnibuses. It is the invention of Messrs. Moxon, Clayton, & Fearnley, of Rochdale. All the working motions are on the outside, and freely accessible. It has one shuttle, with underpick worked from the first shaft, the picking rods moving on end alternately to take and miss the hammer. It makes ninety picks per minute. The wire-motion inserts forty-five wires per minute, one wire for every two picks; and it is the principal feature in the loom as in most other carpet looms. The wire-motion is noticeable for the facility and promptitude with which it inserts the wires on which the loops or pile is raised, and for the simple mechanism for holding the wires when inserted, and withdrawing and transferring the point of the wire for re-insertion. The ordinary Jacquards, weaving Brussels carpet, insert only twenty-six wires with fifty-two picks per minute. This loom produces six yards of carpet three-quarters of a yard wide per hour—two yards more than the ordinary loom. The wire motion is regulated by means of one cam.

The warp is controlled by three healds, which command respectively the stuffer warp of three threads in one dent, the binder warp of two threads, and the coloured worsted of one thread. The pattern is printed upon the warp threads of worsted, and afterwards wrought into the web. The healds are raised and lowered by levers worked over a three-grooved cam or tappet-wheel, and are so worked in forming the shed that the binder warp crosses alternately the stuffer and the worsted warp. The stuffer never comes to the surface; the binder does, but is not seen; and thus, with one-fifth of the worsted used in the ordinary Jacquard, an equally good effect is produced. The letting-off motion depends upon the blow of the reed on the cloth; the taking-up motion is similar to that of most carpet looms, and has a pointed-tooth card on

the breast roller calculated to put in the required number of wires per inch.

The motion for seizing, withdrawing, and inserting the wires, is various in different looms, so also is the mode of placing the point of each wire into position for insertion. These minute but salient points have been and continue to be a fruitful subject of litigation between the proprietors of the several patents relating to them.

4. *Shearing Machine*.—This machine is made for shearing silks, fustians, velvets, carpets, and moleskins, after having undergone the process of raising. There are two revolving cylinders, making 1,000 turns per minute, with five helical steel cutters to each cylinder, $3\frac{1}{2}$ inches diameter, 37 inches long, the cutters being inclined in contrary directions. The web to be shorn is passed under endless traversing leather bands, with cards to clean and lay the nap one way, and under the two shearing cylinders successively. The noticeable feature is the application of two cylinders instead of one, by which the web is shorn at one operation instead of being passed twice under one cylinder.

CHAPTER VIII.

LOOMS EXHIBITED BY MESSRS. WM. SMITH AND BROTHERS, HEYWOOD, NEAR MANCHESTER.

Messrs. Smith exhibited three looms for heavy works,—a woollen, a half-woollen, and a damask loom.

1. *Woollen Loom*.—This loom is adapted for weaving heavy Scotch tweeds, Scotch carpets, Venetian carpets, and woollen cloths two yards wide. It has an underpick, working "three shuttle cranky;" in other words it has three shuttles, with a rising box capable of changing the shuttle every pick, and working "pick and pick," or the "odd pick." It makes 65 picks per minute, weaving a 74-inch web, the reed space being 78 inches; and can turn off 30 yards in a day.

The shedding motion of this magnificent machine, in which there are twenty-four healds, is performed by means of two sets of jacks, above and below, connected together, and working the healds between them. They are worked by a dobby, or demi-Jacquard, called an index machine, which also regulates the pick and produces the pattern. The lags and pegs of the index machine act, like those in Messrs. Dickinson's dobby loom, upon hooked wires connected with jacks, pushing back one lot, and leaving the remainder unmoved; then, by a double-acting motion, the one lot is lifted and the other lowered, so as to form the shed with half the traverse that would be required if it were

wholly formed by lifting one set of wires, and leaving the others stationary. The lifters for raising and lowering the hooked wires, and the heald in connection with them, are worked from a cam on the end of the first or crank shaft, which works an intermediate lever connected to the lifters. This lever acts at the same time on an eccentric bar or stretcher, over which the yarn passes, which vibrates in unison with the shedding motion, so as alternately to take up the slack and give way, to keep the warp at a uniform tension. The shedding cam is so formed as to "dwell" the shed, or keep it stationary for some time, during one-third of a revolution of the crank-shaft, to allow sufficient time for the passage of the shuttle. When the shed collapses, the hooks are brought to a level, by "levellers" bolted to the lifters, into position for receiving the next impression from the lags and pegs, to form the next shed.

The lag-chain is turned on a barrel or prism, so as to present the lags successively to the wires; the barrel derives its motion from the first shaft through a pair of mitre wheels driving an upright shaft, which carries an intermittent wheel at its upper end—a plain wheel, in fact, without teeth—with a single pin, which takes into the notches of a star-wheel on the prism shaft, and turns it one notch at a time for each revolution of the crank-shaft.

The slay or batten reciprocating movement is communicated, not, as in the usual way, by cranks on the first shaft, but by grooved cams keyed on the shaft, which engage with friction-rollers on the ends of two "arms" or brackets on the back of the "slay-sword." The cams are so shaped as to cause the slay to rest or dwell, when drawn back, a little longer than the dwell of the shed-cam, whilst the shuttle traverses the warp; after which the slay is promptly driven up to the web and again withdrawn. In economising time, space is also economised, for, instead of the 6-inch traverse of the slay with the cam motion, a crank motion would require eight or nine inches throw to give time for the shuttle to pass through the shed. The cam motion for the slay is perfectly convenient for the moderate speed of this loom, and it is identical in principle and purpose with Taylor's crank-arm; it moreover admits of the use of a straight shaft for the first motion, which for a heavy loom is a material advantage; and, with a dwell in the slay and in the shed conjointly, an inferior quality of yarn can be worked, and with a lower shed.

The drop-box, or rising shuttle-box motion, is worked by means of two short chains, one supplementary to the other, performing precisely the same office as the single long shuttle-box chain applied to Mr. Hall's fancy loom. This is an ingenious plan, the invention of Messrs. Smith, for doing away with the great length of single chain required. The function of the first chain is to time the changes; that of the second

is to execute them. The second chain, on this combined system, remains stationary under the lever for moving the shuttle box, so long as the same shuttle is required in use; to make a change of shuttle, it is advanced by one link, which may be higher or lower than the preceding one, and will raise or drop the box accordingly. There are, therefore, just as many links in the second chain as there are changes of the shuttle in the pattern. Duplicate, or repeating links, are thus got rid of, and the chain gains immensely in cheapness and compactness. The first chain, having very easy work to do, may be made very light; it contains as many links as there are picks in the pattern, and is turned upon a prism by one link at a time for each pick. A pointer or peg, on the end of a lever, is dropped upon each link as it arrives, which presents a blank surface to the peg, so long as the same shuttle is to be used; but when a change of shuttle is to be made, the peg falls into a hole in the link presented to it, when the heel of the lever carrying the peg advances a pin laterally into gear with a star-wheel on the axis of the second chain, and turns it an eighth part of a revolution. By this movement a fresh link in the second chain is brought up, and shifts the shuttle-box.

By means of the picking motion, with a rising or drop box at both ends of the slay, the loom is capable of throwing any number of picks, odd or even, from each shuttle. An additional jack is mounted in the jack-frame to work the picking motion, and is provided with a hook in the hook-frame, acted on by a special line of pegs in the lags. According as the hook is drawn up or down, the jack moves the right or the left hand picking rod longitudinally, with its finger, into the line of the picking hammer, to receive the blow, and perform the pick. The upper end of the picking stick is let into and through a brass picker, which slides between a pair of fly spindles, and is made with a driving stud having a socket filled with india-rubber, to strike and to receive the shuttle on its return. This is an excellent and novel arrangement of picker; it ensures with the underpick a steady and parallel action on the shuttle,—the shuttle, in other box looms, being received against a stop in the box.

The taking-up motion for the cloth is positive, and is worked from the first shaft by a train of wheels and worms to a worm-wheel on the cloth-beam, which is covered with brass carding, as emery or fluted rollers do not bite. This motion is extremely convenient for reversing in search of a fault, as it all goes back together with the first shaft and other motions; and, for the purpose of reversing, there is a second or cross belt for the backing motion, which saves hand labour for that purpose, so that a female can attend to the loom. Another taking-up motion may be applied to the loom, consisting of the weighted ratchet-motion already described,

as in Mr. Hall's fustian loom. The let-off motion is of the usual kind, with friction-chains on the yarn-beam.

2. Half-Woolen Loom.—This loom is adapted for heavy and light fabrics, as linen, cotton, wool, and mixed goods. It has 38 inches reed space, and a three-shuttle rising-box on one side only for any even number of picks, with under-pick. This arrangement is always understood for weaving checks, and the loom may be called a three-shuttle check loom. It was weaving trowsersings, 36 inches wide, from cotton warps, and a weft made of a mixture of wool and cotton; it made 140 picks per minute, and was capable of turning out 40 yards per day. The shed is formed by light tappets or cam-wheels on the end of the first shaft, working eight healds through upper and lower jacks: lifting two healds, and dropping six. The tappets bring the yarn level and straight, just as the reed arrives at the web, thereby reducing to a minimum the strain on the healds from the blow of the slay.

The motion of the slay is derived from cranks on the first shaft, in the usual manner. The rising shuttle-box motion is precisely of the same kind as for the woollen loom: by means of two chains—one with a pointer to time the changes of shuttle—the other with links of different sizes to execute the changes. The first chain is moved once for every two revolutions of the crank-shaft, or for each double pick—not for each pick, as in the odd-pick loom.

The picking motion is given direct from the crank shaft; the upper end of the picking shaft works in a double scroll, like a figure "8" doubled up, fixed on and revolving with the crank shaft; the picking shaft is thus moved on end, for every turn of the crank, alternately up and down, so that the finger on the picking shaft at each end is struck by the hammer on the first-motion shaft every alternate revolution, and gives regular even picks. This is the usual plan for taking underpick off the first motion—provided for in Messrs. Platt's loom by shifting the picking finger and leaving the picking rod stationary. A segmental "finger" proceeds from the lower end of the picking shaft, and is connected by a strap to the lower part of the picking stick, to give it motion. The upper end of the picking stick passes through the lathe and through the picker; and this mode of picking dispenses with the spindle or picker-rod, saves oil, and prevents oily spots on the cloth.

The taking-up motion is arranged with one beam, regulated with the increasing diameter of the cloth-beam. The ratchet-wheel motion is applied in an ingenious manner to take up a very minute feed at a time, by means of eight ratchets extending over a large ratchet-wheel, taking in one-eighth of a tooth-space at a time, instead of a whole tooth at a time, as in ordinary; so graduating the take-up in a more

nearly uniform manner. To equalize the feed, with the increasing diameter of the beam, a flat piece of wood is applied to the lower side of the web-roll, sustained by a system of levers. As the roll is enlarged the wooden bearer is depressed, and shifts the end of a link in a slotted lever, so as to gradually shorten the play of the ratchets and equalize the take-up. A vibrator, carrying the warp at the back of the loom, is moved by a cam on the crank shaft, following the shedding of the warp, and equalizing the tension upon it. The let-off motion is on the usual method of friction chains over the yarn-beam.

3. *Damask Loom*.—This loom is constructed like the ordinary calico loom, with 45-inch reed-space; weaving a web 42 inches wide, making with the underpick 160 picks per minute, and 25 yards of cloth per day. It is fitted with the double-lift Jacquard of Messrs. Crossley Brothers, Failsworth, by which a beautiful damask pattern was produced. The peculiar effect of damask, it may be observed, is made by carrying certain threads of the warp over the substance of web for several picks consecutively; and it is the aim, in the double-acting Jacquard, to keep up these threads so long as they are required to be up, by means of the double-acting lift, and to expedite the formation of the shed and the production of the loom. The Jacquard has 400 needles and 800 hooks—being two hooks to each needle; one of these hooks is longer than the other, in order to keep the double rows of hooks as near together as possible, and to give room for placing the two lifters, or “grives,” one above the other—one lifter for the upper or long hooks, the other for the lower or short hooks. Each pair of hooks is connected to the threads and lingoes, or weights attached to the warp threads, and the threads are lifted precisely in the same way by one or by the other hook, whichever of the lifters is in action. As the pattern is repeated three times in the width of the web—that is, it is described four times—there are four warp threads to be lifted by each pair of hooks. The grives take their motion from a double crank on the second shaft, alternately raising one and dropping the other, once for each pick, or for each revolution of the crank-shaft. By this process of double action, the formation of a new shed is commenced at the same time that the previously formed shed begins to come down; and the sheds cross each other half way. The warp threads, which are to remain up, are taken in charge by their alternate hooks and carried back, with the other threads picked up from the level, to form the next shed. By such means two sheds may be formed in the same time that the single-acting Jacquard forms one. The descending lingoes balance the ascending ones, and they do not exhibit the least tendency to bounce or swing. The inventors maintain that, in practice, 50 to 60 more picks are made

per minute by their loom, with the double-acting Jacquard, than by any other machine. It is stated that the weaver at this loom is paid 1s. 8d. for 37½ yards, and makes fully as much money at that rate as when paid at the rate of 2s. 6d. for the same length at the ordinary damask loom. The “cylinder,” which is in fact a square prism for changing and presenting the Jacquard cards in succession, is turned by a small crank on the end of the first shaft.

The underpicking motion is the invention of Messrs. Todd, of Heywood; it has already been referred to, as applied to the plain loom of Messrs. Booth & Chambers. Most underpicks are worked from the first shaft, but in this system the underpick is worked from the second shaft, and admits of the loom being reversed without throwing the shuttle. The chief peculiarity is in the form of the striking surfaces of the hammers and the picking finger, which are flat, and strike flat, to give a quick and sharp pick. The picking finger is, in fact, the end of a short lever hung at the middle, the other end engaging a strap attached to the picking stick.

The taking-up motion is what is called the “emery roller” motion; but, in place of the emery roller, there is a cast-iron roller, fluted and chased. The cloth-beam is pressed upon the “emery roller” by means of upright racks, pinions, and suspended weights. The yarn-beam is of wood, but is usually made now of wrought iron gas-pipe, which is less than half the weight of a cast-iron roller, and nearly as cheap as wood, and is a great improvement in looms.

4. *Pirn-winding Machine*.—In this machine three different modes of filling the pirn for the shuttle were shown. In one, the pirn was placed, with the smaller end downwards, in a cup fixed to the rail of the machine. As the pirn is filling it rises in the cup, and, when full, the flat blade of the spindle, which carries the pirn, leaves the groove in the wharf, and ceases to be turned by it, and the pirn stops. In the second plan, the spindle, on which the pirn is placed with the thicker end downwards, is kept up to the cup by a weighted lever applied to its lower end. The spindle carries a drum the length of the pirn, by which it is driven; and, as the pirn fills, it forces the spindle and its drum downwards through the driving-band till the latter slips off the drum and upon a loose pulley, and the spindle stops. In the third plan, the spindle is fixed, and carries the pirn with the thicker end downwards; as it fills, the cup rises, and with it the guide-wire; when full, a small feeler and catch allow a bar to come into contact with the lifter, and throw off the belt. In each of the three modes described, each spindle is independent of its neighbours, and may be filled and emptied without stopping the machine.

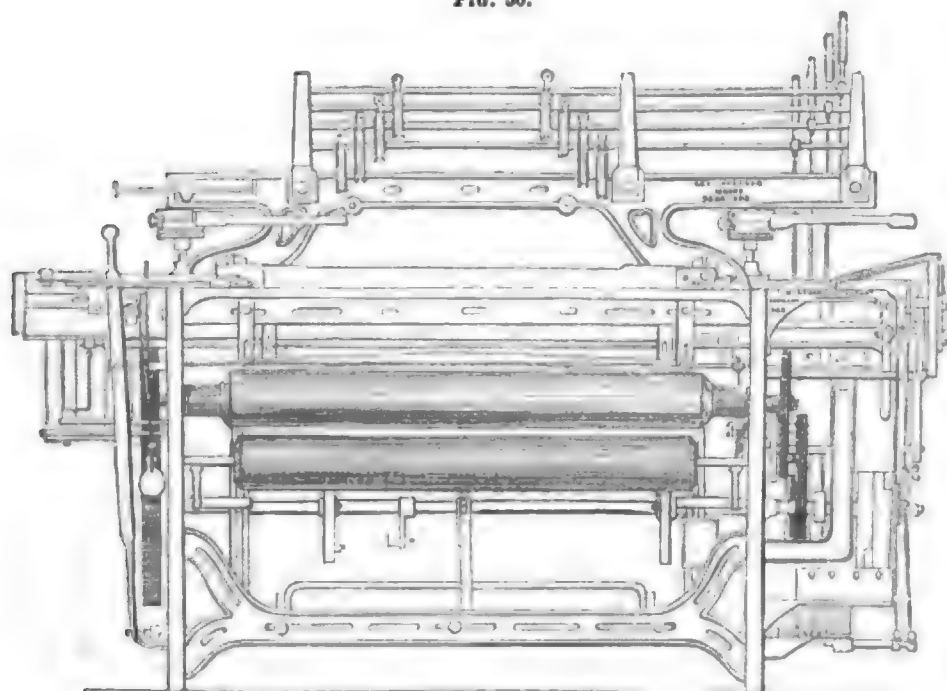
CHAPTER IX.

LOOMS EXHIBITED BY MR. GEORGE HODGSON, BRADFORD.

Mr. Hodgson exhibited five looms adapted for weaving dress goods, of substantial proportions, and well constructed.

1. *Plain Orleans Loom.*—This is a narrow loom with loose reed and overpick, weaving a 27-inch web. At the usual speed it made 170 picks per minute; but it has made 430 picks per minute. It is suitable for weaving all sorts of plain cloth, such as Orleans, Cobourgs, shalloons, satins, and calico, or for any other treads where light goods are used; and it is considered by the exhibitor to be capable of run-

FIG. 56.



PLAIN ORLEANS LOOM, by Mr. George Hodgson, Bradford.

ning as fast as any loom yet made. The shedding motion is of the kind used in Bradford for from two to eight leaves or healds; it is made by means of treddles placed outside the loom at one end, worked by cams on the second shaft. Square "jack-rods" are laid above the healds, reaching from end to end, to carry the jack-levers and "half-moons," "quadrants," or circular segments, for lifting the healds vertically. The jack-levers are fixed in pairs on the jack-rods by set screws, one pair to each heald. The quadrants are connected by adjustable chains to the healds, and their back levers are connected at the back of the loom by rods to the treddles. The vertical picking shafts are placed inside the end frame-plates of the loom; not outside, as in the Lancashire plain looms. The taking-up motion is of the "emery-roller" class, with iron fluted rollers. The yarn-beam is held by ropes, levers, and weights (fig. 56).

2. *Alpaca Loom.*—This loom has a fast reed and overpick. It weaves a 42-inch web; the usual number of picks is 140 per minute. It has one shuttle, and may have two, three, or five treddles. This loom was weaving alpaca cloths of the finest manufacture. The warp was of black cotton, the weft of forties alpaca, very fine, making twenty yards per day. The taking-up motion has Salt's patent roller, which is covered with lined cloth, and works in connection with a fluted iron roller.

3. *Check Loom.*—This loom has an overpick, and makes 200 picks per minute. It has a revolving circular shuttle-box with six compartments for six shuttles, which, with the method of working it, was originally patented by Mr. Luke Smith, of Heywood, and was afterwards improved by Messrs. Titus Salt, Sons, & Co., of Saltaire. The shuttle-box revolves, precisely on the principle of the "revolver," and presents the different shuttles to the picker as required for the pattern. It is worked by a sort of double-acting ratchet-motion, in which there are two spears directed towards the shuttle-box, one over and one under, one or other of which is brought into contact with the box when it is required to change the shuttle, pushing it round forwards or backwards one shuttle-space at a time according to the shuttle wanted for the pick. The spears are moved by a pair of tappet-wheels on one end of the first shaft, through a pair of hinge-back levers, which give way

to avoid a breakage should the shuttle not be thrown clear of the box for the previous pick, and prevent its revolving. The pick is regulated by a set of cards with two series of holes and blanks, one for each spear; two pointers or pegs are acted upon and brought into contact with the cards, and when stopped by blanks the shuttle-box is turned one shuttle at a time, either way, according to the pointer so engaged. When blank cards are presented to the pointers, the spears are held out of gear with the shuttle-box, which remains stationary. In other looms Mr. Hodgson turns the shuttle-box by means of hooks for pulling it over, instead of spears for pushing it.

4. *Twilling Loom.*—This loom weaves plain diamond twill square, or satin, and may be changed at pleasure from one to the other without stopping the loom. It may have either

twelve or sixteen healds suspended from double jacks overhead, linked to work together in a sort of parallel motion. The healds are lifted evenly by the jacks, and they drop with the assistance of springs. The shedding motion is effected by a very simple and effective arrangement, Martin & Bottomley's patent, like an inverted Jacquard motion, with cards. Vertical rods, double-hooked at the lower ends, are suspended from the outer ends of the jacks between two treddles worked by a pair of ordinary plain Orleans tappets. The rods, when not subjected to the action of the cards, — when perforations are opposed to them, — are retained by springs in contact with one of the treddles, which, taking their hooks on one side, pull them down and raise the healds every other pick. When blank cards are pre-

check loom; but instead of tappet-wheels for moving the levers they are moved, like the healds, by the treddles, with two long rods and jacks, the motion being regulated by two series of holes and blanks on the cards. The taking-up motion is worked by a special jack (fig. 57).

This loom is a most creditable production, and exhibits much ingenuity in the detail. It is particularly well adapted for weaving the German twill plaids, and possesses the advantage of a Jacquard machine up to twelve or sixteen healds.

5. Oddpick Loom.—This loom is designed for weaving oddpick cloth, with loose reed and overpick, and two shuttle-boxes at each end, which slide horizontally for changing the shuttle and making the oddpick. The shuttle-boxes are shifted by means of cards and tappets.

In the motion for stopping the loom, should the second thread break,—that is, the thread immediately following the oddpick thread, there is a provision for lifting the oddpick thread, by a fork from the back of the lathe, out of the way until it is wanted for the return of the shuttle belonging to it.

In Mr. Hodgson's looms, though more costly than the Lancashire looms, the workmanship is excellent, and the details very complete; indeed, in some respects luxuriously, and, as some people consider, needlessly so. Two intermediate bearings are applied to the first and second shafts of the wide looms, and one additional to the fast narrow looms, which enable the looms, no doubt, to work with great solidity and steadiness. But there is a fashion in Yorkshire, and there is a fashion in Lancashire, and

the material pays for the fashion.

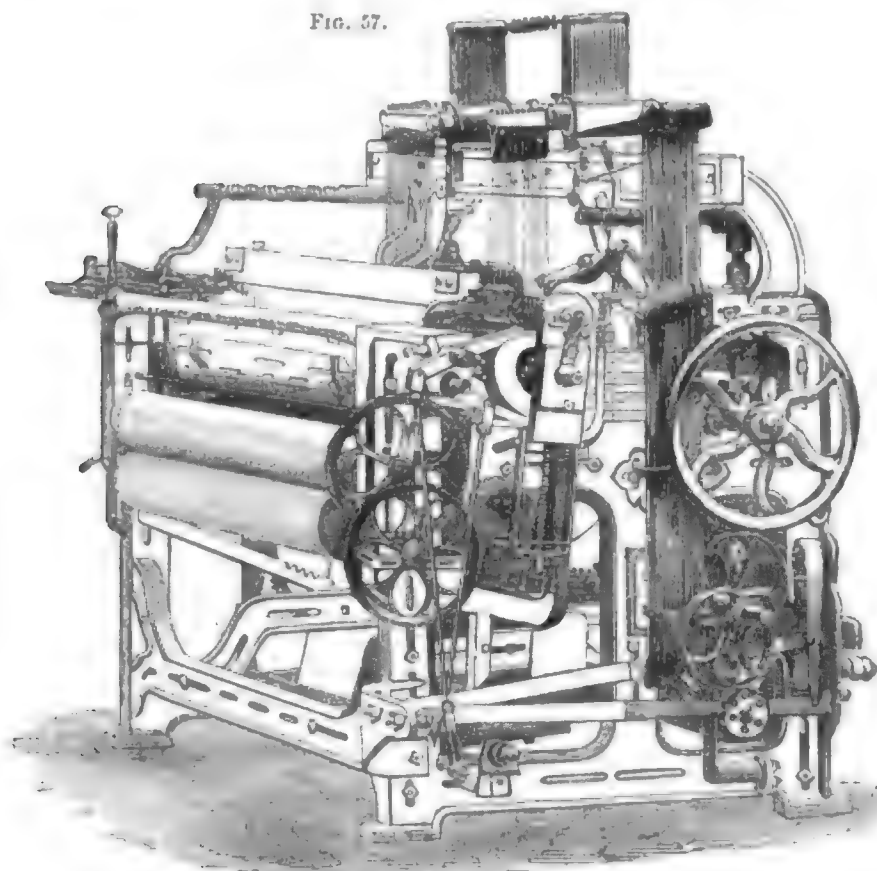
CHAPTER X.

LOOMS EXHIBITED BY MESSRS. G. HATTERSLEY AND SON, KEIGHLEY.

Messrs. Hattersley exhibited two looms for weaving dress goods, similar in construction to Mr. Hodgson's looms.

1. Six-shuttle Loose-reed Loom.—This loom is fitted with overpick, and a revolving box for six shuttles. It was at work with three shuttles, weaving *barège*, making 190 picks per minute,

FIG. 57.



TWILLING LOOM, by Mr. George Hodgson.

sented to the rods, they are pushed over to the other treddle, which in its turn catches the alternate hook, and pulls them down every alternate pick. As the action of the treddles is confined to pulling down the rods and raising the healds, it is apparent that any shed may be formed by passing the hooks of the proper rods under one treddle or the other. When one heald is to be kept up for more than one pick consecutively, the rod in connection is not moved, and the heald remains stationary; consequently the warp does not work. There is also provision for keeping up the healds until they are required to drop, when they are kept down by the springs.

The loom is fitted with overpick, and is provided with a revolving shuttle-box for six shuttles, worked by spears and hinge-back levers as in the

having a 39-inch reed-space. The shuttle-box is turned by a pair of hooked rods which pull it round instead of pushing, as in some of Mr. Hodgson's looms. The motions of the shuttle-box are directed by means of an endless train of sheet-iron cards hung at the back of the loom with two series of holes and blanks, and two points dropping over the cards. The cards are changed once for every two picks by means of a star-wheel on the axis of the prism which carries them, the star-wheel being turned round one notch at a time by a pin on a special second motion. The pulling rods for the shuttle-boxes are put in action through two levers connected to them, one to each, the other ends of the levers being hooked on when required to one of a pair of catches suspended from a vibrating lever which receives its vibrating motion from a cam on the end of the second shaft. This motion by pulling is preferable to the pushing motion by short spears.

The shedding motion is made with three healds and segmental jacks, as in Mr. Hodgson's ordinary loom; the taking-up, letting-off, and weft motions are also the same.

2. Jacquard Loom.—This loom has a 29-inch reed space, and is of the same construction as the other, with a Jacquard in combination for working the healds. The Jacquard motion lifts the healds, and they are dropped by the aid of springs as in Mr. Hodgson's loom, with this feature in addition, that the bottom board of the Jacquard on which the wire-hooks rest, is made to lower and carry down the unhooked wires and their healds, at the same time that the hooks on the lifter rise, making the shed with half the traverse that would be necessary with a single-acting lift, and allowing the yarn to come to the level during each revolution of the crank-shaft. Both the lifter and the bottom plate are vibrated by means of a single crank on the end of the first shaft. The pattern cards for regulating the healds have two rows of holes in each, each card giving two sheds: thus reducing the number of cards that would be required if single, to one half; and the frame holding the needles is raised and lowered alternately by a cam on the second shaft to bring the upper and lower rows of holes in each card consecutively in front of the needles. Fifteen healds were at work in this loom, and it is adapted for eighteen healds.

The shuttle-box motion for six shuttles is similar in principle to that of the first loom, and is worked off the pattern-cards with an additional row of holes and an evenpick. The lever that works the treddles for turning the shuttle-box has its fulcrum on a spring-detent which gives way in case of accident, and prevents breakage. There is a groove in the bottom of each shuttle-case to guide the picker and keep it upright. The shuttles are stopped against the picker, and the picker is guarded by a friction-roller from

the cross action of the points of the shuttles when the shuttle-box revolves. A 24-inch web is woven at the rate of 170 picks per minute.

CHAPTER XI.

MACHINES EXHIBITED BY THE ANDERSTON FOUNDRY COMPANY, GLASGOW.

The Anderston Foundry Company exhibited two fancy looms, with a novel system of pattern barrels, designed to supersede the pattern or tappet chains common in English looms for working two or more shuttles. They exhibited also a winding machine, the invention of Messrs. Robertson & Orchar, of Dundee.

1. Pirn or Weft Winding Machine.—This machine is designed for winding woollen, cotton, or silk. There are two novel features in the construction and action of this machine. First, the upright winding spindles are driven by means of friction-discs, the faces of the discs on the spindles running on and being turned by the rims of a series of discs on a horizontal shaft. Gearing is thus dispensed with for this motion. Second, the variable speed of the spindles is obtained by vibrating the driving disc-shaft on end, in order to move the driving discs alternately to and from the centre and the circumference of the spindle-discs. Thus the speed of the spindles is varied in proportion to the varying diameter of the conical winding surface of the cop, on which the thread is traversed upwards and downwards; and the speed of the uptake, and tension of the thread, are rendered uniform. The cone-builder rests on the cop, and rises as the pirn becomes filled, and the cop, being built with such regularity and compactness, is said to take up from 20 to 25 per cent. more yarn than with other machines, saving consequently something in waste and in cost of winding, and reducing the number of stoppages of the loom, for replenishing the shuttle. There is a saving in driving power with the friction-wheels. For winding heavy yarns of from 16 to 48 lb. per spindle, the machine is said to be superior to other machines; and it can be made to wind for two different sizes of cops or pirns.

2. Check Loom.—This loom is the invention of Messrs. Muir & McIlwham for weaving fancy goods. It is worked by overpick, and has a four-shuttle drop-box at one end for even picks. The chief novelty consists in the "pattern-barrel," to regulate the picking motion, which serves the purpose of the picking chains in Messrs. Smith's and other looms, and is moved by a ratchet-motion derived from a cam on the second shaft. The barrel is a cast-iron cylinder, 12 inches diameter, with a

continuous helical line of holes drilled in it; each hole represents one double pick, and the line of holes winds a sufficient number of times to form the pattern. The use of the holes is to receive flat-headed studs which are screwed into them at proper intervals and at various elevations above the surface of the cylinder. For working four shuttles, the studs are placed at three different elevations, and the surface of the cylinder constitutes a fourth elevation; and the series of studs are precisely equivalent to a series of cams or to a tappet-chain with four sizes of links. By a very peculiar arrangement, the fluctuations of a lever under which the studs slide whilst the loom is in action and the stud-cylinder revolves, are transmitted to a system of three levers, hung loosely in a frame, corresponding to the three elevations of the studs. These levers lie underneath a group of three cams of various throw, which revolve on the second shaft, and which produce no effect whilst the levers play loose. But, with the vibrations of the stud-lever over the studs, one or other of the levers becomes locked in the frame containing them, and is depressed by the cam revolving over it; this motion is transmitted to the shuttle-box, and it is thereby raised to the proper elevation for delivering the required shuttle. When the stud-lever slides in contact with the cylinder, all the cam-levers are loose, and the shuttle-box is at its lowest position, right for the uppermost shuttle. The shuttles may be presented in any required order.

The pattern-barrel is reversed by a self-acting motion; and the succession of the shuttles and the pattern are consequently also reversed. Thus the pattern is regularly worked out from one end of the barrel to the other, and repeated backwards and forwards. The loom was weaving a pattern of 90 picks with four shuttles; but with 12 inches length of barrel, giving twelve turns of the pattern-holes and studs, 750 double picks or 1,500 single picks may be had in a single traverse of the cylinder, and 3,000 picks to complete the pattern in a double traverse.

There are four healds, suspended by straps over rollers, worked by four treddles driven by four cams which are turned from the second shaft by means of bevil gearing proportioned as two to one, to turn at the same speed as the first shaft.

The loom has 41 inches reed space, and makes 130 picks per minute, working with four shuttles. It can make 145 picks if there are only three shuttles to work; but with five shuttles, the speed falls to 125 picks per minute. The limit to speed is imposed by the necessity for waiting till the shuttle-box completely falls or rises to the required level, and it may be easily understood that the action of changing the shuttle is hard upon the shuttle-box, the cams, and the gearing in connection.

3. *Check Loom, No. 2.*—This loom is adapted for weaving fine muslins, striped, twilled, and

plain. It has an underpick, 41-inch reed-space, a two-shuttle rising box, and makes 150 even picks per minute. It has four leaves or healds. It was employed in weaving twill, making the shed with three leaves up and one down, changing the heald for every shed. The pattern-barrel is much narrower than in the other loom, being only 3 inches broad; it differs from the last also in having two functions to discharge:—first, with one circle of holes and studs to work the changes of the shuttles, giving 240 single picks to form the pattern; secondly, with a second circle of holes and studs to regulate the formation of the twill by doing two things:—to disengage the take-up ratchet and stop the take-up motion when required, and to form the shed. The healds are suspended from a double set of jack-levers overhead, acting as a parallel motion similarly to the twilling loom of Mr. Hodgson's, with the difference that instead of moving the healds by the jacks overhead, they are moved from below, whilst the jacks overhead are, with the healds, sustained in position by spiral springs. Instead, therefore, of lifting the healds by power, and drawing them down by springs, as in Mr. Hodgson's loom, they are drawn down by power, and lifted and sustained by springs. The healds are drawn down by means of four jacks below the web placed across the loom, from which four hangers are suspended, one to each. When the jacks are to be pulled downwards, the hangers are placed in connection with their respective treddles, which are worked by four cams on the second shaft. The treddles pull them down accordingly, and with them the healds to form the shed. When the hangers hang free from the treddles, the healds remain up. The motion for engaging the hangers with the treddles acts simply by pushing them into contact with the ends of the treddles, when they notch together. A special wyper-shaft is driven by spur-gear from the second shaft, making one turn for four of the crank-shaft, and carrying four wipers which revolve behind the hangers; each wyper in turn pushes the hangers successively into connection with the treddles, and thus the motion is accomplished.

CHAPTER XII.

LOOMS EXHIBITED BY MESSRS. J. AND W.
WHITESMITH, GLASGOW.

Messrs. Whitesmith exhibited two check or "multi-shuttle" looms for the production of fancy fabrics, as the Scotch clan tartans and German twilled plaids.

1. *Check Loom.*—This is a loose-reed overpick loom, on Mr. Whitesmith's patent, with a six-shuttle rising or drop box. It has a reed-space of 33 inches; and it was weaving a web 24 inches

wide, making from 150 to 165 even picks per minute. The shuttle-box motion is regulated by means of cards,—in this instance, forty in number,— $\frac{3}{4}$ inch broad, hung in front, over an eight-sided “cylinder” or prism, with two rows of holes and blanks, and two points to drop over them. The shuttle-box is raised and lowered in connection with a horizontal lever having a segmental rack on one end, gearing with a toothed pinion fixed on a stud with a couple of tumblers, on a level with the second shaft. The motion is delivered from a single crank on the end of the second shaft, which works two palls or hooks, one to act above and the other below the two tumblers respectively. By the agency of the cards and the points, which are raised or lowered by means of small corresponding levers connected with the point-levers by wires, one or other pall turns the tumbler and pinion in either direction, and so elevates or lowers the shuttle-box, as required, for the change of shuttle, changing one at a time. A third rod proceeds from the same crank to communicate the vibrating motion of the card-cylinder to and from the points. The taking-up motion is positive, with an emery roller,—the system chiefly followed in Glasgow. The letting-off motion consists of the common friction-ropes and weighted levers.

2. Check Loom.—The checking or shuttle-motion of this loom is on Mitchell & Whitelaw's patent, and is fitted with a three-shuttle drop-box worked similarly to the shuttle-box of the other loom, but capable, in addition, of skipping a shuttle. The shuttle-motion is regulated by pattern-cards, which regulate also a twilling motion, on Mr. Whitesmith's patent. For these objects, the cards have four series of holes and blanks, and four points are dropped over them. The three changes of shuttle are made as before, by means of two tappets and pushing rods worked from a cam on the second shaft; with this peculiarity, that one tappet determines the two extreme positions of the shuttle-box, and thus provides for the action of the first and third shuttles, whilst the other tappet determines the middle position of the shuttle-box, and provides for the action of the second shuttle. Thus, by the separate or combined action of the two pushing rods and tappets, any one of the three shuttles may be at once brought into action. For working the shuttle-box, two of the points are applied on the cards. The two remaining points operate on the twilling motion, which is driven by two tappet-wheels in such a way that, by arranging the cards suitably, the loom, in the course of working, changes from plain twill or *vice versa* at any moment, so as to produce fabrics partly twilled and partly plain. The loom makes from 140 to 155 picks per minute.

These looms are adapted for fabrics varying in weight and character, from stout druggets or heavy cotton ginghams up to the finest dress

winseys and lustres, including mixed fabrics of cotton, worsted, alpaca, mohair, and silk, with from one to six shuttles. The twilling motion being perfectly automatic, weaving twill or plain at will, an extensive command of pattern can be secured by its use.

Note.—Messrs. Whitesmith exhibited, in connection with the above, two spindles of their three-cone anti-friction winder, arranged on each loom so as to wind the spools for filling the shuttles. The peculiarity consists in sustaining and guiding the pirn or bobbin between three cast-steel cones revolving on inclined axes, the object of which is to wind the finest or the most delicately coloured yarns without injury, there being no surface friction as in other winders. The cones are adjustable to wind various sizes of bobbins, with a diversity of yarn at the same time. This system of winding has been found to be very successful in the winding of fine silk yarns, and in particular for the winding of wet silk, in which it supplies a desideratum long felt.

Although, as exhibited, the winder can be neatly adapted to the looms, and, being driven from the loose pulley of the loom, may continue to wind whether the loom is going or at rest, yet the main object was to show the new principle of winding, it being generally recommended to have the winding spindles on separate machines.

CHAPTER XIII.

ENGLISH CARPET LOOMS.

During the last eleven years extensive changes have been made in the machinery for carpet-weaving, arising from the introduction of the power-loom. The application of steam-power weaving to tapestry carpets had been found so successful that, according to the Jury Report on carpets, Messrs. John Crossley & Sons, of Halifax, naturally turned their attention to the manufacture of Jacquard-loom carpets by steam power, stimulated in this enterprise by the specimens of power-wove Brussels carpets, which Mr. Bigelow, the American inventor, had sent to the Great Exhibition of 1851 just before its close. They succeeded in producing a power-loom for Jacquard carpet weaving, capable (in 1862) of turning out forty yards per day,—more than double that made by the original loom of Bigelow, and five or six times as much as an ordinary hand-loom could produce in the same time. Hand-loom Jacquard weaving is now almost entirely superseded by steam-loom Jacquard weaving.

It is stated, further, in the Jury Report, that the leading carpet fabrics of English make are the Jacquard Brussels, and the tapestry or printed carpet; the former with figures raised by the Jacquard process, and employing from two to

five frames or warps of differently coloured worsted; the latter being of a single warp only, printed by separate threads at a time, with any number of colours in each thread, subsequently woven into a cloth. The tapestry carpet, simpler and more economical than the Jacquard Brussels, was the invention of the late Mr. Richard Whytock, of Edinburgh, who disposed of his patent to Messrs. Crossley. In their hands, the manufacture of tapestry carpets attained to great perfection in detail, and the result has been to establish the seat of this manufacture at Halifax. Brussels and velvet-pile carpets made in the Jacquard loom, are made chiefly at Kidderminster, where, in 1772, 250 hand-looms produced all the carpets then required; now, there are upwards of 400 power-looms, besides hand-looms, with twelve times the rate of production.

The extraordinary influence of the new commercial treaty between France and England, in promoting the demand for English carpets, is manifest from the fact that the annual average of the four years' exports, before the treaty, from 1857 to 1860, amounted to 48,279 yards, value £7,508; whereas, in 1861, the first year of the treaty, 472,952 yards were exported, of the value of £61,269.

The tapestry carpet-loom exhibited by Messrs. Tuer & Hall (now Mr. Robert Hall), has already been described with their other looms exhibited.

Messrs. Jackson & Graham, of London, exhibited one of Crossley's Jacquard looms for weaving Brussels carpet. Messrs. Henderson & Co., of Durham, also exhibited a Jacquard loom for weaving Brussels and velvet carpets. The motions for withdrawing, transferring and inserting the wires, were of different kinds in the respective looms; but the withdrawing motions were on the same principle, in which the end of a lever, worked by a tappet, is connected with the apparatus which holds the wire. The yarn, which is dyed, is wound on bobbins hung in frames behind the loom, each frame containing 260 bobbins. There are five frames of bobbins, which is the number generally employed in making good carpets, making in all, 1,300 bobbins or warp threads. Of these, only one-fifth, or 260 threads, rise by means of the Jacquard action to the surface of the cloth at one time, to form the pattern; the remaining four-fifths of the warp threads floating through the ground or base of the fabric. In the arrangement of the bobbins, the warps of the proper colours are put into their proper places in the frames. In the process of weaving a pattern of a large design, the bobbins require occasionally to be taken out of the frames and replaced by others.

The loom of Messrs. Jackson & Graham made 52 picks per minute, and was capable of weaving 32 yards of carpet per day. That of Messrs. Henderson & Co. made 90 picks per minute, and was capable of producing about 40 yards of best or five-frame cloth per day of ten and a half

hours. It works on the "single-shed" principle, though it may be adapted to work by "double-shed," on which principle it may produce 50 yards of three-frame cloth per day. It is arranged also for weaving printed warps. It has a worm taking-up motion, and is well and carefully finished.

A loom for weaving Axminster carpets, it may be observed, was contributed from the United States, and will be described in the chapter on Foreign Looms.

CHAPTER XIV.

FLAX AND HEMP WEAVING MACHINERY, EXHIBITED BY MESSRS. C. PARKER AND SONS, DUNDEE.

The exhibition of looms for weaving linen, sailcloth, and sacking, with dressing and winding machines, was reserved for Messrs. Parker, of Dundee, whose sailcloth and other power-looms are well known.

1. *Mathematical Sailcloth Loom*.—They exhibited their "mathematical" sailcloth loom, to weave 30 inches wide from four beams. The principal features are, first, the letting-off motion, in which the yarn is passed between two rollers and round a third roller covered with woollen cloth. The first two rollers are geared together by an intermediate stud-wheel, and driven by a worm and worm-wheel, the third roller being kept down by the draw of the warp. Secondly, the taking-up motion is effected by means of self-adjusting weighted levers acting on a worm shaft which gears with a toothed wheel on the cloth beam, the weights being thus moved nearer the ends of the levers as the cloth-beam increases in diameter. The lay or "beat-up" is worked by cranks. The shed is formed and the shuttle is thrown by an overpick motion, as in the Blackburn calico loom.

2. *Jute Loom*.—This loom was designed for weaving jute sacking, bagging, and other coarse fabrics, plain or twilled, 29 inches wide. It has an ordinary letting-off motion by means of friction ropes on the yarn beam, an overpick motion, a positive taking-up motion, and a rolling-back motion, by which the warp can be taken back, from the front of the loom, without the necessity of raising the weights or going behind the loom. The merit of this loom consists in the taking-back motion, the pin-roller taking-up motion, the throwing of a large shuttle and making a proper shed for it.

3. *Fine Linen Loom*.—This is an underpick loom, to weave cloth 36 inches wide, with a new bar-motion in front for easing the warp when the reed delivers the blow, and so reducing the

chance of breaking the warp threads ; and an improved mode of picking through the slay.

4. *Five-Shuttle Linen Loom*.—This loom is made with a five-shuttle drop-box, to throw variously coloured wefts, with overpick.

5. *Warping Machine*.—This machine is 60 inches wide, for linens or jute. The yarn-beam is driven by a disc friction-plate, adjustable to any strength of yarn, and superseding the cylinder and change-rings for various widths.

6. *Dressing Machine*.—This machine, for linen or jute, dresses two beams at the same time, with large metal cylinders and fanners for drying, circular brushes, pressing rollers, disengaging, measuring, and marking motions, &c.

7. *Warp-winding Machine*.—This machine has 24 spindles, for winding any quality of linen or jute yarns, with a rack traversing motion.

8. *Weft-winding Machine*.—In this machine, with 32 spindles, for linen or jute, the winding is performed on horizontal spindles direct from the palk to the shuttle-bobbin or pirn, the spindles being driven by friction-discs.

9. *Weft-winding Machine*.—This machine has ten upright spindles, suitable for heavy canvas yarns, to wind from the bobbin.

CHAPTER XV.

FOREIGN LOOMS.

In the Foreign section of the Western Annex, several looms were exhibited, chiefly from France.

FRENCH LOOMS.—M. Mercier, of Louviers, was the principal exhibitor of looms, of which he showed two underpick woollen looms at work. The first had a single shuttle ; the second was a three-shuttle rising-box loom. They were good ordinary slow looms, of the kind mostly in use on the Continent, with the old hand-loom motions of seventy years ago. The picking motion is effected by means of a powerful spring at each end, which is the motive-power to throw the shuttle, and the springs are taken in for the next pick by means of cams. This spring motion does not possess any practical advantage over the picking-stick, which is sufficiently elastic in itself. The motions are taken off the first shaft by means of bevil gearing, which it is not judicious to employ where spur gearing can be applied. The lathe or slay is worked by cams instead of the ordi-

nary cranks, by the use of which, no doubt, for a long driving shaft, the strength and stiffness are preserved. The cams are so formed as to cause the lathe to "dwell" whilst the shuttle is being thrown. There is a good self-acting motion for stopping the loom by means of a single pulley, representing both the fast and loose pulleys ; it is put loose on the shaft, to which it is connected for driving, and from which it is instantly disconnected when the shuttle sticks, or a weft-thread breaks.

Messrs. Durand & Pradel, of Paris, exhibited a Jacquard loom of the old construction ; but, instead of the square "cylinder" and cards, they substitute for cheapness a round "cylinder," to work with a continuous sheet of thin paper. The cylinder is caused to revolve continuously—the feelers, as they approach and recede, pointing to the centre of the cylinder. The loom was not at work, but it cannot probably make more than 80 picks per minute.

M. Bacot, of Sedan (Ardennes), exhibited a three-shuttle woollen loom, with a single-acting Jacquard motion ; it is designed for weaving heavy woollen cloth. The shuttles are shifted horizontally by a motion regulated by the Jacquard. The loom was not worked, nor was it in working order ; and probably never wove the piece of cloth with which it was mounted.

M. L. Bruneaux, Jun., of Rethel (Ardennes), exhibited a woollen loom with double-acting Jacquard, on Postel's system. It had fifteen healds, which formed the shed, by parting from the level equally up and down. The chief noticeable feature was the short crank-arm with which it was fitted, to give dwell to the slay, in the manner of Taylor's motion for the same purpose, exhibited by Messrs. Dickinson & Sons. The slay had 12-inch "ears" cast on, with 6-inch crank-arms, and 3½-inch cranks.

M. Mouline exhibited a calico loom, in which the shuttle is moved by magnetic action instead of by percussion.

M. N. Berthelot, of Troyes, exhibited three stocking looms—two circular, and one rectilinear,—called the Troyes frame. In these looms there are means for giving equal tension to the yarn, and for weaving figures ; there is also a good stop-motion. In the rectilinear loom there is introduced, in addition, an ingenious mode of narrowing, by which the piece is formed ready for joining.

MM. E. Tailbouis & Co., St. Just-en-Chaussée, exhibited a rectilinear loom, by which they are enabled to weave four to six stockings at one time in a frame. The narrowing is performed automatically, and the needles are supported by bars.

MM. Fouquet & Franz, Stuttgart, exhibited several circular knitting machines, in which the length of the mesh can be varied by merely turning a screw, and the mesh is firmly retained in the course of formation.

Messrs. Baudouin Brothers & Jouannin, of

Paris, exhibited a self-acting power-loom for weaving nets, in cotton, flax, hemp, or silk. The loom is on the system of Buron & Pecqueur; it has 153 shuttles, and can produce at least 1,300 knots, or nine rows of knots, per minute, and is adapted for weaving middle-sized nets for catching codfish, herring, &c. The knots are made exactly like the fisherman's knots, and give a loop-selva. The net-lap varies from 50 to 250 meshes in width, according to the number of shuttles in the loom, and it may be divided as required into several separate strips with loop selvages. By combining threads of contrary twist, the shrink, when the net is wetted, is effectually prevented. In the tightening of the knots in the loom, each thread is allowed sufficient freedom to ensure the regularity of selva. For the manufacture of wide fishing nets, or drag-nets, a loom with 51 shuttles is employed.

BELGIUM.—Messrs. Houget & Teston, of Verviers, exhibited a woollen loom for plain work. The slay is worked by means of a cam acting on a series of bell-cranks—a system which is frequently employed to make the slay strike the web twice after each pick, to drive up the thread, and make a cloth of close texture.

AUSTRIA.—Mr. W. Schramm, of Vienna, exhibited a single-acting Jacquard loom, in which the second motion is dispensed with, having oak sticks instead of metallic wires, which, of course, add to its bulk. It was remarkably well made, particularly the comber board, and was very cheap.

SWITZERLAND.—Messrs. Wahl & Socin, of Basle, exhibited two single-acting Jacquard looms for weaving figured ribbons—one for four, the other for eight ribbons, or other narrow work, as for upholsterers' consumption. The machines are well made, and make excellent work, but on the old single-acting principle, and slow in their motions. The four-ribbon loom makes 70 picks per minute, and the other 60 picks. They could have been constructed to make twice as many picks in a minute; but as they are now constructed, they would tumble to pieces if it were attempted to work them so quickly. The lingoes have too much freedom, and the crank for working the Jacquard has a great deal too much throw, with a needless swing on the machine. The crank might have been made much shorter, with advantage in point of steadiness and speed.

ITALY.—M. E. Vincenzi, of Modena, exhibited a Jacquard machine, in designing which the object has been to admit of the use of cards of reduced size, and about half the usual thickness. M. Vincenzi has aimed at making the smallest possible needle-hole, and packing the holes closely together. In English practice, the object is to get the holes as large as possible;

they are already made as small as they can judiciously be made, allowing for the expansion and contraction of the cards.

Signor G. Bonelli, of Turin, exhibited the electrical loom, with which his name has been for some time associated. He has long been known as a scientific and practical man, and has for many years past had his attention turned to the application of electricity as a substitute for the Jacquard apparatus in the loom; but he has only lately been able so to perfect his arrangements as to bring them before the commercial world in a form which he considers adapted for general use.

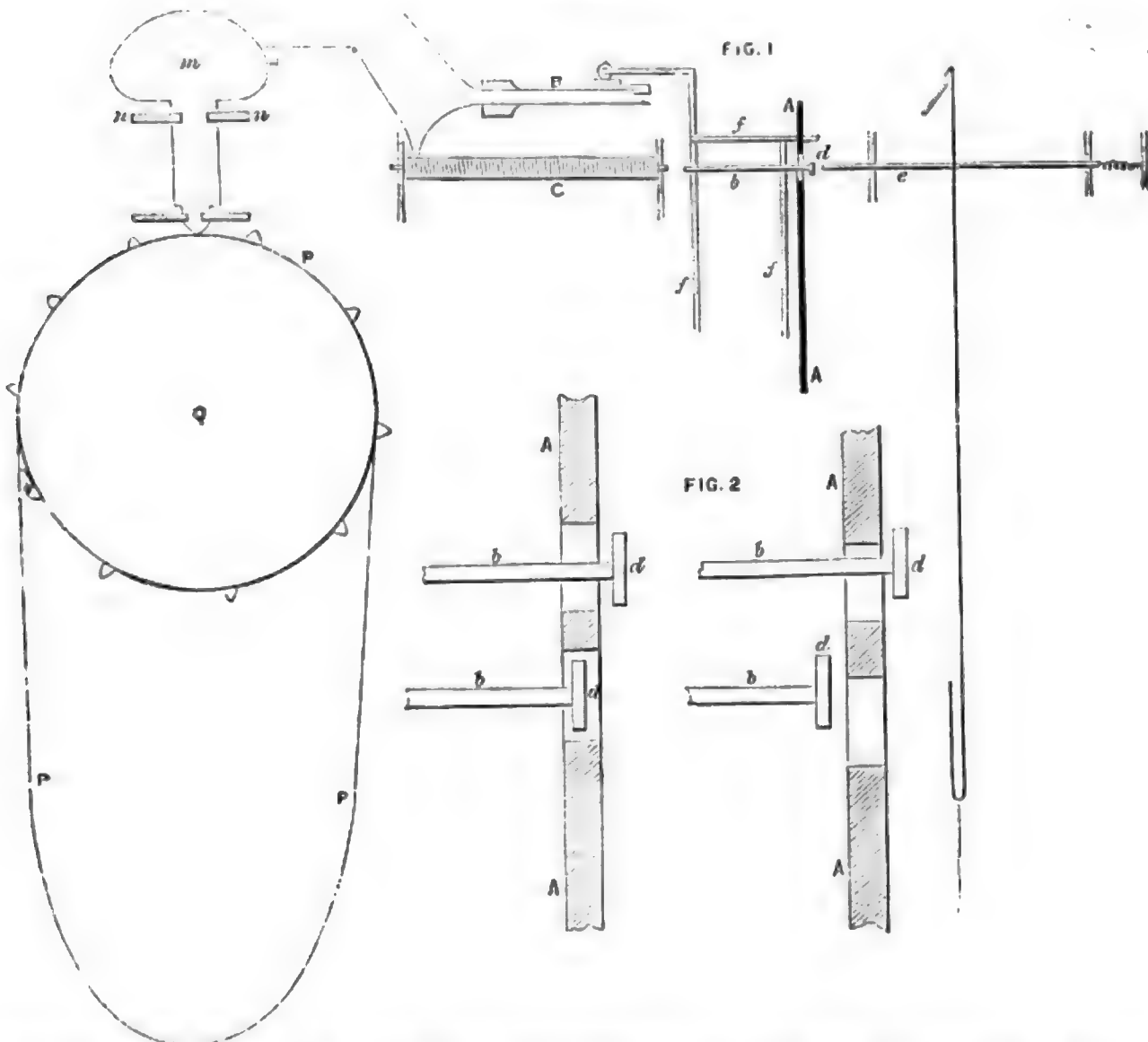
So long ago as 1854, Signor Bonelli constructed an electrical loom, which was exhibited at that time in Turin; but the first trial to which the machine was submitted gave but small hope to those who saw it that the inventor would succeed in his object. The public trial at Turin, in 1854, in the presence of manufacturers, was not so successful as to remove all doubts as to the merits of the novel apparatus. In the following year it was submitted to the judgment of the Academy of Sciences, at Paris, who appointed a committee to examine it; but it is believed that no report was ever made. In 1855, a model of the loom had a place at the Universal Exhibition, at Paris; but the lateness of its arrival there prevented any official report being made in reference to its merits. Since then, Signor Bonelli has devoted much time and attention in endeavouring to remedy its defects and to perfect its working, so as to render it capable of holding its place in the factory. The Author is again indebted to Mr. Foster's able paper, already referred to, for the following excellent description of the loom:—

In the first place, it must be understood that the special object of Signor Bonelli's machine is to do away with the necessity for the Jacquard cards used to produce the pattern at the present time,—the chief source of delay and a source of very considerable cost, more especially in patterns of any extent and variety of treatment. Signor Bonelli uses an endless band of paper, of suitable width, the surface of which is covered with tin-foil. On this metallized surface the required pattern is drawn, or rather painted, with a brush in black varnish, rendering the parts thus covered non-conducting to a current of electricity. This band of paper, bearing the pattern, being caused to pass under a series of thin metal teeth, each of which is in connection with a small electro-magnet, it will readily be conceived that, as the band passes under these teeth, a current of electricity from a galvanic battery may be made to pass through such of the teeth as rest on the metallized or conducting portion of the band; and from such teeth, through the respective coils, surrounding small bars of soft iron, thus rendering them temporary magnets, whilst no

current passes through those connected with the teeth resting on the varnished portions. Thus, at every shift of the band, each electro-magnet, in connection with the teeth, becomes active, or remains inactive, according to the varying portion of the pattern which happens to be in contact with the teeth. In a movable frame opposite the ends of the electro-magnets, which, it should be stated, lie in a horizontal direction, are a series of small rods or pistons, as Signor Bonelli terms them, the ends of which are respectively opposite to the ends of the electro-magnets. These pistons are capable of sliding horizontally in the frame, and pass through a plate attached to the front of it. When this

frame is moved, so that the ends of the pistons are brought into contact with the ends of the electro-magnets, they are seized by such of them as are in an active state; and, on moving the frame forward, these are retained, while the others are carried back with it, and, by means of a simple mechanical arrangement, become fixed in their places. Thus, there is, in front of the frame, a plate with holes, which are only open where the pistons have been withdrawn; and this plate, as will be readily understood, acts the part of the Jacquard card, and is suitable for receiving the steel needles which govern the hooks of the Jacquard, in connection with the warp-threads as ordinarily used (fig. 58).

FIG. 58.



ELECTRIC LOOM, by M. Bonelli. A, perforated plate; C, electro-magnets; b, rods moving in the frame f, and forming the armature of the magnets, with heads d, opposite the needle e, of the Jacquard; m, thin metallic plates, insulated by comb-like material m m, in which they are inserted, and bearing on the sheet P, carrying the design, hung on the cylinder Q; B, contact-breaker. At a given moment, the plate A is slightly lowered, as in fig. 2, which prevents the heads d passing.

Each shift of the pattern, combined with the backward and forward movements of the frame bearing the pistons, produces a different series of holes in the plate, which thus becomes what may be termed a universal Jacquard card, changing its face at each contact, in accordance with the requirements of the pattern. Thus it is con-

templated in the electric loom to get rid of all those costly preliminaries which are required for the preparation of the cards, accomplishing instantaneously and automatically an analogous operation.

With the loom exhibited in the Western Annex, 40 to 50 picks per minute were made

by hand, and it was stated that from 100 to 120 picks could be made by steam power. The limit of speed, it is said, is not in the electrical apparatus, but in the Jacquard itself. For 1,000 cards, it is acknowledged, the electrical appliances are not worth substituting. For 5,000 cards, they could be substituted advantageously, in point of economy. The width of pattern is 16 inches for 400 wires, for which it is stated a five-cell battery would be required, costing twopence per day for materials.

Signor Bonelli gives an example of the comparative cost of Jacquard cards and the electric appliances. He takes a damask design requiring 4,000 cards and 400 Jacquard wires. The cards, at 12s. per hundred, cost £24. The time for preparing and reading the pattern and punching the cards is about five weeks. On the electric system, the executing of the design on the metallized paper is estimated at £6; the time, one week. The cost of the electric apparatus to be adapted to the looms at present in use, is said to be about £20.

The loom was at work in the Western Annex, but it was subject to frequent interruptions; and something remains to be done for it before it can take the rank of an approved working machine.

UNITED STATES.—A novel power-loom for weaving "tufted pile" fabrics, invented by Mr. H. Skinner, of New York, was exhibited at work by Mr. A. Smith, of the same place. It is designed for weaving "Axminster" carpets, rugs, and mats, which are commonly woven by hand by the process termed "finger rug-weaving." The tufts are cut from an endless series of worsted bobbins, 270 in number, dyed in conformity to the pattern, the threads of worsted being wound on each bobbin, of different colours, ranged side by side, each contributing one row of tufts to the web. The threads of each successive roller vary of course in arrangement, 270 rows of tufts having been required for the completion of the pattern that was wrought in the loom. Seven rows of tufts, three-quarters of a yard wide, are inserted per minute, for fixing which three picks are made for each tuft, or 21 picks per minute. There are five rows of tufts to the inch forward, and twenty yards per day are turned out. By the hand-loom, one minute at least is required to fix one row of tufts, turning out at this rate only three yards per day.

To perform in succession so many movements, some of them of a complex character, it may be conceived that this loom is complicated in construction. The endless series of worsted bobbins is shifted forward one bobbin at a time, and at one part of the circuit it passes close to the reed of the loom; at the proper moment an apparatus lays hold of the nearest roller, unhooks it, and brings it down to the yarn while the reed is

back, when a bar under the warp-yarn, which carries a series of pincers, approaches, and passes the pincers through the yarn; the pincers seize the ends of the worsted yarn on the bobbin, pull them down through the warp, and return with the worsted to the upper side of the warp. In this situation a knife approaches, and cuts off a breadth of tufts from the bobbin, the double ends of the tufts remaining upwards like the letter U. The bobbin, now set free, is replaced on the endless chain, and the chain is moved to pass forward the next bobbin. Meantime, the shuttle is passed three times to weave in the staples of worsted, and to form the back of the web.

Looking further into detail, the warp is divided into three parts,—the body warp of cotton, the tuft warp of cotton, and the binder warp, to bind the fabric together, of linen or cotton. These warps are controlled by three healds, worked by three cams or tappets, on the end of the second shaft, acting on treddles. A fourth cam inside the frame lifts the nippers, which are opened by a fifth cam, and closed by a spring. On the side of the fifth cam, a sixth cam is fixed, to draw down the wool to form the tufts, move it sideways, and pass it up again through the warp. The wool is held in place by a comb, moved by a seventh cam, till the shears, moved by an eighth cam, come up and cut off the tufts. The same cam moves an arm which unhooks the bobbins from the frame. The bobbins are brought into position one at a time by a ninth cam, in concert with a ratchet-motion on a small roller over the slay. The slay is worked by a couple of slotted cams on the first shaft, being the tenth and eleventh cams; and the picking-sticks are struck together, from both sides of the loom at once, by means of a twelfth cam with three tips on a sector of a circle. The object of the double action is to make sure of striking the shuttle at all times, at either end of the slay, and completing the odd number of picks without incurring the complication of extra cams and moveable picking-shafts, which it was judiciously considered could not be afforded.

Besides these motions for shedding, picking, and tufting, by the instrumentality of nine cams inside the loom and three cams outside, there is an ordinary ratchet-wheel taking-up motion; also the letting-off motion, by means of a ratchet motion combined with a movable roller sustained by a weighted lever, by which the tension is regulated.

The designing of this loom has necessarily involved an enormous quantity of contrivance; and, considering that it is the first of its kind, the inventor deserves great credit for the perseverance and resource with which he has worked out the invention to a successful issue. It is open, no doubt, to simplification and improvement in detail, but it must command the attention of English machinists.

CHAPTER XVI.

SUNDRY MACHINERY.

Spooling Machine.—Exhibited by Messrs. Sharp, Stewart, & Co., Manchester. It is most ingeniously contrived,—the invention of Mr. W. Weild, Manchester. In a descriptive paper on this machine, read before the Institution of Mechanical Engineers in May, 1861, Mr. Weild mentions that attempts have been made to wind thread by self-acting means on to several spools at the same time; but that, as a large portion of the winder's time is occupied in placing and removing the spools, and in fixing the ends of the threads to them, the advantage was found insufficient to induce perseverance for overcoming the difficulties. Mr. Weild, notwithstanding, invented this machine, in which the entire operation of spooling thread completely by self-acting means is performed; accomplishing the entire process of winding six spools at once. It fixes the empty spools ready for winding, and guides the threads on to them during the winding; and exactly when the required length of thread is wound on, it stops the winding, cuts a nick in the edge of the spool, and draws the end of the thread into it for fastening off; then cuts off the thread and discharges the full spools, and begins winding again on a fresh lot of empty spools. One set of spools, containing 200 yards each, is filled in about one minute, occupying about 54 seconds of that time in winding, and about 6 seconds in changing the full spools for empty ones. One great difficulty that had been experienced at first in getting the machine to work, was to stop winding at the right moment when the spools were full, by reason of the great momentum of the winding parts revolving at such a high speed, which rendered it impossible to stop at the right point, until a powerful friction-brake was adopted, consisting of a strap passing round a pulley of large diameter. By this means the winding is stopped dead at the proper point, but without any shock; and the gearing and spools are all held quite stationary while the changing movements are performed. The machine can be adjusted for any length and form of spool by changing the "shaper-template," which regulates the travel of the thread-guide; and the number of teeth in the ratchet which advances the shaper-template determine the length of the thread, by fixing the number of layers put on the spool. The thread is delivered on to the spool through the spring fingers of the thread-guide, the pressure being adjusted by a set-screw, to give it a uniform degree of tension throughout the whole winding, and by this means to ensure the delivery of the exact length of thread. Two reversing springs are very ingeniously employed in connection with the shaper-template, for reversing the travel of the thread-guides; as the tracing finger moves along, it charges one of the springs gradually,

whereby it is suddenly thrown down and up alternately at the two ends of its travel across the template, and is returned under or over the template.

One machine fills on an average 18 to 20 gross of spools per day, including stoppages for the supply of thread, &c. It requires only the attendance of a girl, and it does not require the degree of skill necessary in hand-winding. One self-acting spooling machine of six heads will do the work of six hand-spoolers. It has been estimated that upwards of three thousand persons are employed in the United Kingdom in spooling sewing thread by the hand machines, producing between three and four millions of spools per annum.

Card-Setting Machine.—Exhibited by Mr. T. Crabtree, Halifax; it is well constructed, and differs slightly from the original machine of Mr. Dyer.

Heald-Knitting Machines.—Messrs. Cook & Hacking, of Bury, exhibited a self-acting machine designed to knit a perfect heald of any counts or any width, entirely without hand labour, and arranged to make either plain or braided edges, with a self-acting stop motion when the yarn breaks or is run out. It makes only a single knot. The machine exhibited was delicate, and subject to get out of order; but, having been the first one made of the kind, probably the existing defects may be remedied.

Mr. G. Ward, of Blackburn, exhibited a heald-knitting machine worked by an attendant. It is a good practical machine, and is extensively in use. It makes single and double knots, and is so arranged that the eye of the heald as it is formed is passed on to a rod. The machine does half the work, doubling the thread below, the attendant turning it over above. The machine does the braiding, the attendant ties the knot. The taking-up motion is worked by spur-gearing instead of worms, and admits of the machine being reversed and run back every time the heald is changed. It makes 1,000 stitches per hour, or 10,000 per day; and makes healds of any counts required, and of any depth from 10 to 18 inches, embracing the varieties of healds used in weaving cotton, worsted, silk, or linen. The machine is capable also of knitting space-healds required for figured fabrics.

Silk Velvet Loom.—Messrs. J. & R. Robinson & Co., of London, exhibited a Spitalfields loom in operation in the Process Court, worked by hand. The work produced was excellent in quality, and small in quantity—about half a yard a day.

Fulling Machines.—Messrs. Ferrabee & Co. exhibited a good fulling machine. Similar machines were exhibited by M. Mercier and Messrs. Houget & Teston, of a kind in general

use on the Continent, and which has now almost superseded the old fulling mill. In the old mill, the cloth is beaten by a pair of heavy swing mallets; in the new mill, it is passed between a pair of rollers requiring only half the motive power, besides better regulating the width and length of the pieces.

Tentering and Drying Machine.—Mr. Lee Norton exhibited a cloth-tentering and wool-drying machine, by means of which one man and a boy will dry, in a space of 12 yards by 3, 2,000 to 2,500 yards of cloth in a day, irrespective of the weather; whereas, by the old system of large drying houses, heated stoves, and out-of-doors drying, it requires eight or ten persons to do the same work.

Brushing Machines.—The machines exhibited are of ordinary construction, and such as are in universal use. By means of the brushing machine the nap of the cloth is raised.

Shearing Machines.—The machine exhibited by Messrs. Tuer & Hall, now Mr. Hall, has already been noticed, with the looms exhibited by them. Several others are shown by Messrs. Houget & Teston, and by Mr. Thomas, of Berlin. Mr. Thomas's was a double-cutter machine, like Mr. Hall's, and was the best machine of the kind exhibited. It is well and strongly constructed, and is fitted with various appliances and means of adjustment, the benefits of which are fully appreciated by practical workers, who are aware how readily one of these machines, unskilfully handled, may cut or destroy a piece of cloth. In Mr. Thomas's machine, an eccentric cam is introduced, for lowering, with the greatest degree of nicety, the revolving cutter in the successive stages of the process nearer to the cloth; whereas, in the ordinary machine, a piece of tin is put under the adjusting screw, for the level at the first cut, and is taken out to give the level for the second cut, permitting the knife to work more closely to the cloth. There was also a motion for lifting the knife or revolving cutter over a joint or a fringe. Again, the knives derive their lateral motion by means of a chain and pinion, which is safer and neater than the ordinary rack. The spiral blades are soldered into the roller, instead of being fastened as usual by a screw. If well done, it ought to do; but there is difficulty in preserving the temper of the knives in the process.

Fringe-making Machine.—M. E. P. Villain,

of Paris, exhibited a simple machine, in which the material is drawn off the bobbin, twisted, and sewed upon tape, so as to form a fringe; and the twist in the cords of the fringe is made permanent by the application of heat.

Braid-making Machine.—M. J. B. Laneuville, of Paris, exhibited a simple machine to make twenty-four braids at a time.

Five-Roller Calender.—The calender exhibited by Messrs. John Kerr & Co., Dundee, is designed for finishing linen or cotton goods. There are five rollers arranged vertically over each other in a frame. The top and bottom rollers are of cast iron, 20 inches in diameter, on wrought-iron shafts to sustain the pressure put on them whilst at work. The middle roller is 11 inches in diameter, made hollow, and fitted with stuffing boxes at the ends for the reception of steam pipes, or with an opening to admit hot bolts if required. The two intermediate rollers, 24 inches in diameter and 54 inches long, are constructed of sheets of brown paper densely packed and compressed, turned and polished, the surface consisting, in fact, of sheets of paper on edge. The calender is driven by gearing from a first shaft making 80 revolutions per minute, having two belt-pulleys 34 inches in diameter and 8 inches wide, for open and cross belts, with a double friction-clutch between them for starting, stopping, and reversing. The middle roller is driven from the first shaft, and makes 20 revolutions per minute.

The calender is adapted for plain calendaring when the cloth is passed between the rollers; for chesting or rolling the cloth on the top roller under heavy pressure; for mangling or rolling the cloth on the second roller from the top, when the end of the piece is sewed to the body of the cloth, and the calender is turned backward and forward under heavy pressure; for glazing, a drag or slip being made between the centre roller and the lower cast-iron roller, the centre roller being heated by steam or by hot bolts to produce a high degree of glaze; and for rubbing, by the action of two revolving helices at the front of the calender rubbing over the surface, and equalizing the distance apart of the warp threads. The pressure is caused by weights suspended by a chain over a pulley, which carries a pinion on the same shaft gearing into a "horse-head" lever, which conveys the pressure to the rollers, with a screw motion to adjust the levels. The pressure is equal to 20 tons inclusive of the rollers.

SECTION VI.

SEWING MACHINES.

CHAPTER I.

INTRODUCTION.

The rapid progress of the sewing machine—a comparatively recent invention—towards maturity, has been very frequently remarked; and justly so. The art of machine-sewing or stitching, distinguished from embroidery, was scarcely known in 1851, and was represented at that time by two very imperfect machines. In 1855, at Paris, not fewer than fourteen varieties were exhibited; in some of which the best practice of the present time was exemplified. In 1862 there were exhibited about fifty different arrangements of sewing machines.

The manufacture of sewing machines is one of the most important branches of industry now carried on in America, where they are extensively used. Several Joint-Stock Companies have been established there within the last nine or ten years, for working the patents of different inventors. In some of these manufacturing establishments sewing machines are regularly turned out at the rate of from 400 to 800 per week. The estimated total number of sewing machines in use in America is 300,000, of which about 75,000 are employed by private families.

At the lowest computation, one sewing machine is fully equal to five hand-sewers. Taking the ordinary price of this class of labour in America—somewhat higher than in England,—every machine will save two dollars, or about 8s. 6d. per day, in wages alone, which amounts to an aggregate saving in America of upwards of £29,000,000 per annum. According to the last census returns, the capital invested in real and personal estate in this business, in nine of the United States, during the year ending June 1, 1860, was £289,656, employing 2,194 hands. The cost of labour was £221,520, and 116,330 machines were made, valued at £1,167,780. In England, the general introduction of sewing machines has been retarded by litigation and by other causes; but within the last two years their use has been greatly extended. The best American machines, which were formerly excluded, have been largely imported since the expiration of Thomas's patent of 1846.

The introduction of the sewing machine necessitated a considerable modification in the art of sewing itself. Attempts had been made at imitating ordinary hand-sewing by the aid of a needle inserted into and drawn through the fabric by mechanical fingers or nippers; but it was found necessary to abandon altogether the conventional system of stitching, and to invent

other modes of uniting fabrics by threads or filaments better adapted to the powers of machinery. The use of detached lengths or needlefuls of thread in machine-sewing, with a constantly varying length of slack, soon gave place to a method of sewing whereby the thread could be worked up continuously from a reel or bobbin; an unvarying length of slack was thus presented at each stitch, the tightening or drawing up of which was easily done by machinery. In machine-sewing, one end of the thread is contained in the fabric and the other on the reel, instead of in the needle, as in hand-sewing; the thread, therefore, can only be passed through the fabric in a double or looped form. The most convenient means for effecting this is by a needle having an eye formed near its point. This needle is never passed entirely through the fabric, but is pushed through it only to a sufficient extent to carry a loop of the thread to the other side, and is then withdrawn. By its withdrawal, the needle would naturally carry back with it the loop of the thread it had just introduced; but it is necessary, in order to produce a stitch, that this loop should be retained or secured on the other side of the fabric, either by being interlooped with the thread of the needle itself, or with a second thread, called a filling thread.

There is another distinguishing feature in machine-sewing—viz., the mode by which the different lengths of stitches are obtained. In hand-sewing, the needle is inserted at a different place for each succeeding stitch, the work itself being held stationary; but in machine-sewing, the needle constantly operates in the same plane, whilst the work is moved under it step by step for every stitch, and each step in advance measures the length of the stitch. In a complete sewing machine, three subordinate combinations of mechanism are provided:—First, a stitch-producing mechanism, combined with appliances for maintaining the necessary degree of tension on the threads; second, nipping or holding surfaces for supporting the material against the thrust and withdrawal of the needle, at the part where the stitch is being formed; third, self-acting and adjustable propelling mechanism for feeding the material along, step by step, as soon as each stitch is completed.

The sewing machine, as may be supposed, was not at once originated as a matured invention, but was matured by degrees. The first useful application of machinery for stitching was made for purposes of embroidery. In 1755, M. Weisenthal, a German, produced embroidery from a single thread, carried by a double-pointed needle, with an eye in the centre, which was pushed into and drawn through the material by nippers

or pincers operating on both sides. Mr. Walter Hunt, New York, constructed, in 1835, an imperfect sewing machine in which he introduced—and was the first to introduce—a stitch, now known as the “lock-stitch,” produced from two continuous threads, supplied direct from spools or bobbins, and interlocked within the fabric; but there was no means of applying tension to the threads to tighten the stitches, and the machine was eventually set aside as useless. Newton & Archbold, in 1841, patented, in England, a machine for tansouring or chain-stitching the backs of gloves,—scarcely available as a sewing machine. Mr. John Greenough, of the United States, patented, in 1842, a machine for applying the “shoemaker’s stitch” from a single thread, by the aid of the double-pointed needle previously invented by Weisenthal (fig. 59). The only relic of this machine is the

FIG. 59.



THE SHOEMAKER'S STITCH, for Sewing Machines;
by Mr. John Greenough.

model in the Patent Office at Washington. Mr. Leonard Bodwick patented, in America in 1843, and in England in 1844, a running-stitch machine, producing the running-stitch, as made by hand, by means of a pair of toothed wheels working together, to crimp or corrugate the fabric, which was fed between them, and pushed by their action on to a stationary needle (fig. 60). Machines of this description are

FIG. 60.



THE RUNNING STITCH, by Mr. L. Bodwick.

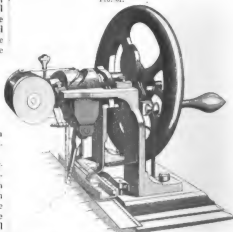
largely used in bleach and dye works, and in the lace trade, for joining piece-goods and sewing on lace edgings.

In 1844, Messrs. Fisher & Gibbons, of Nottingham, patented two ingenious machines for embroidering lace falls for ladies' bonnets, of which the first operated by means of two loopers, each supplied with continuous threads, forming the stitch now made by, and known as that of, the Grover & Baker Sewing Machine. The second machine successfully produced the lock or shuttle stitch by means of needles and shuttles, and wanted little to make it practically available as a sewing machine, though it does not appear that either Fisher or Gibbons contemplated its application in this capacity. It has been stated, with some probability of truth, that the loop-stitch originated by Mr. Fisher, the inventor of the machine, was copied and embodied in the

Grover & Baker (American) machine. Subsequently, after the date of Howe's patent, Mr. Fisher adapted one of his machines for sewing.

In 1846, Mr. Elias Howe patented, in America, the famous sewing machine known by his name. He produced a lock-stitch by means of a curved needle having an eye near the point to carry the upper thread attached to the end of a vibrating lever, and working in conjunction with a shuttle carrying the lower or filling thread. The needle, on penetrating the cloth, carried with it a loop of thread, and through this loop, before the needle withdrew, the shuttle was passed so as to leave its thread interlocked with the loop of the needle-thread. The needle then withdrew and tightened the stitch, the cloth was moved forward, and the operations repeated. The tension for the shuttle-thread was obtained by passing it through two or more holes in the shuttle; and that for the needle-thread, by applying a friction-strap to the reel. The device first employed by Howe for feeding or propelling the cloth, consisted of a thin metal blade called a “baster-plate,” provided with sharp pins on one edge, upon which the cloth was adjusted by the operator before being put into the machine. This plate was moved step by step through the machine, and when its entire length had been passed, it was readjusted and supplied with a fresh length or piece of cloth. This motion was defective chiefly for want of continuity (fig. 61).

FIG. 61.



ELIAS HOWE'S ORIGINAL SEWING MACHINE. Invented 1845,
patented 1846.

The English patent-right of Howe's machine was sold to Messrs. W. F. Thomas & Co., London, who took out the patent for England in the end of 1846. This was the first patent taken out in England for machines for sewing fabrics irrespective of ornamentation, and was taken out under

the erroneous impression that a valid claim could be made for the use of a needle and shuttle, in combination, for sewing; but the patent had to be modified and in part disclaimed, owing to the similarity it bore to the previous English patent of Fisher & Gibbons, in which the lock-stitch was first practically set forth. There is no doubt that to Mr. Thomas's original endeavours and enterprise is due the introduction of the sewing machine in England at a time when the invention was in a nascent state and required cherishing. So little was the invention appreciated in England, that, in 1846, the agent of the inventor offered it without success to many leading manufacturers and engineers.

Mr. Wickersham (not Mr. Singer, as generally supposed) adapted the first really practical feed-motion to the sewing machine. In 1849-50 he substituted for the baster-plate a wheel having a roughened periphery, combined with a spring pressure-plate or foot for holding the cloth down upon the periphery, which protruded slightly through the surface of the table which carried the cloth. An intermittent rotatory motion in one direction only, was imparted to the wheel, which carried the cloth along by frictional contact only; hence this arrangement was called the "friction feed." The next important step in the same direction, was the introduction in 1851 of the "four-motion feed," another modification of the "friction feed,"—invented by Mr. A. B. Wilson, or by Mr. Johnston, of America: the question of invention being in course of decision before a court of law. In the four-motion feed, a horizontal serrated plate works through an opening in the table of the machine, and receives a to-and-fro horizontal, as well as a vertical, reciprocating motion. The cloth is held down upon the serrated plate by a spring presser foot, with a yielding pressure; it is drawn along by the forward horizontal motion of the feeder, and on arriving at the end of its stroke, the feeder drops slightly below the table so as to release its serrations from the fabric, and when thus freed, it returns to its original position in readiness for producing the next traverse of the cloth. For this purpose, it rises vertically and brings its serrations into contact again with the under surface of the cloth, and then moves horizontally forward as before, carrying the cloth along with it. The four-motion feed was first applied, in England, to the Grover & Baker machine, and it is no doubt the most important improvement that has been introduced into the sewing machine. It affords advantages not obtained with the wheel-feed, although the latter is extensively employed, and answers sufficiently well for heavy manufacturing purposes, without the intricacies of ornamental stitching. Where seams in minute convolutions and sharp curves are to be stitched, the "four-motion feed," operating either on the upper or the under surface of the material, is preferable,—giving greater freedom for guiding the material by the hand of the operator than any

other feeding mechanism. In the "wheel-feed," the needle operates on one side of the feeding surface; but in the four-motion or serrated plate-feed, facility is afforded for operating the needle in the centre line of the feeding surface.

There are, then, three principal classes of sewing machines in common use:—the lock-

FIG. 62.



THE LOCK STITCH, with two threads.

stitch machine, with two threads (fig. 62); the double chain-stitch machine, with two threads (fig. 63); and the single chain-stitch machine,

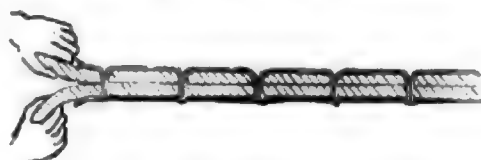
FIGS. 63.



Threads shown loose.



Threads shown closer.

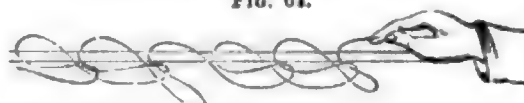


Threads shown taut.

THE DOUBLE-CHAIN STITCH, with two threads.

with a single thread (fig. 64). The lock-stitch, when first invented, was made with the use of a shuttle, and hence acquired the name of the

FIG. 64.



SINGLE LOOP OR CHAIN STITCH, shown loose.

shuttle-stitch. The chain-stitch is known also as the tambour stitch or the looping stitch. In the following notice of the sewing machines exhibited, it will be convenient to associate the English and American machines together, and to notice the continental machines by themselves.

CHAPTER II.

SHUTTLE OR LOCK-STITCH SEWING MACHINES.

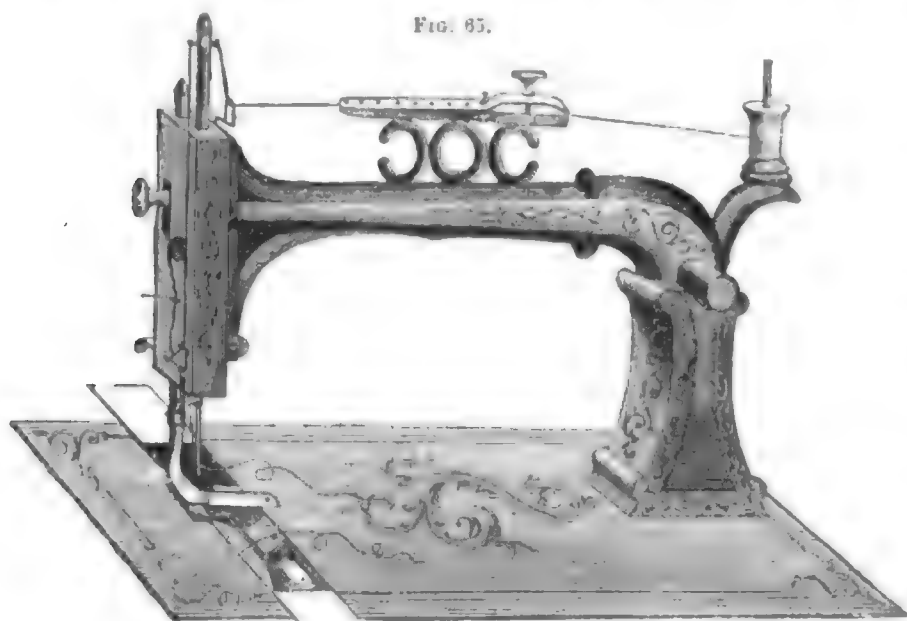
The Howe Sewing Machine Company, U.S., exhibited some excellent examples of lock-stitch machines adapted for family use and for boot and shoe work. They are unsurpassed in point of

workmanship and finish. The platform or flat table machines for family use, mantle-making, and light leather work, are provided with a simple arrangement for holding the needle to one side of the shuttle-race, so as to be entirely out of the way of the point of the shuttle, thereby avoiding the breaking of the needles, which sometimes occurs through the point of the shuttle sticking against them in passing. In most shuttle machines, the shuttle is apt occasionally to miss the loop of the needle-thread, and thus a false stitch is produced,—the integrity of the stitching depending upon the due passing of the shuttle through the loop of the needle-thread. In shuttle machines, the needle, after passing through the material, is caused to be withdrawn slightly for the purpose of opening the loop which it has carried with it sufficiently to allow the point of the shuttle to enter and pass through; and in order that the loop may be caught with certainty, it is requisite that the shuttle, which is made flat on the side next the needle, should pass close against the needle. In Howe's machine, as now constructed, the vertical needle-slide or carrier is made adjustable laterally, so that the needle, whether coarse or fine, can always be brought to work close against the flat side of the shuttle. In his "cylinder machine," intended for boot-closing and for stitching tubular articles, the

good shuttle machines. Mr. Singer was one of the first to introduce the straight needle carried by a slide in lieu of attaching the needle direct to the vibrating lever or needle-arm, which required the use of a curved needle. A straight needle is the strongest and best form, as the curved needle is more liable to spring and break when it meets with any extra resistance in passing through the material. In these machines, the needle-slide is driven by a crank-pin working in a differential slot on the back of the slide in place of by a vibrating lever; and a second shaft, working in the fixed bracket or arm of the machine, carries the crank-pin on its front extremity. Another of the leading features of Mr. Singer's machine is the means for taking up the slack of the needle-thread and tightening the stitch. This is accomplished by means of a spring arm, through an eye in which the needle-thread passes on its way to the needle. The tendency of the arm is to remain elevated, in which position it exerts a certain amount of tension or pull upon the thread sufficient to draw up and tighten the stitch. As the needle-carrier descends, it depresses this arm and allows the thread to follow the needle whilst entering the material. The wheel-feed is used in most of the Singer machines, although some of them are now provided with the "four-motion feed."

These machines are admirably adapted for manufacturing purposes and leather work, in which branches of manufacture they are now extensively used.

Messrs. W. F. Thomas & Co. had a large assortment of different-sized shuttle machines, from the tiny stitcher of collars to the more important-looking tailoring machine. The Thomas machine is well suited for the manufactory, and is very extensively employed in all the Government clothing establishments, besides many others. A straight needle is used, carried by a slide actuated by a vibrating lever which derives its motion from



SEWING MACHINE, by the Howe Sewing Machine Company.

shuttle does not pass through the loop whilst the needle remains in the material, as in other shuttle machines, but after the needle has entirely withdrawn from the material. This simple difference in the operation of the machine produces a vast improvement in the appearance of the stitching; it is much closer and more regular than lock-stitching produced in the usual way. The needle employed for stitching leather articles is generally made three-sided or awl-pointed. The wheel-feed is used in both these machines for propelling the material (fig. 65).

Messrs. I. M. Singer & Co. exhibited some

a cam-groove in a solid fly-wheel. This wheel contains also the two cam-surfaces for driving the shuttle and for actuating the cloth-propelling mechanism of the top four-motion variety. The thread from the bobbin passes through an eye in the end of a short adjustable arm, and thence to an eye in the extremity of an auxiliary lever which is elevated by a pin in the needle-slide, and consequently takes up the slack of the thread and tightens the stitch. The object of this adjustable arm is to regulate the quantity of thread which is drawn from off the bobbin at each stitch, in accordance with the

thickness of the material operated upon, and the length of stitch produced. For this purpose, the arm is raised or lowered slightly, when the variation produced in the angle or direction of the thread, causes more or less thread to be drawn off the bobbin at each rise of the auxiliary lever. This is a very simple and ingenious contrivance for the purpose. The Howe sewing machine has been considerably modified by Mr. Thomas. The curved needle has been replaced by a straight one. The shuttle is worked by a forked driver in lieu of being simply impelled by a blow from

FIG. 66.



SEWING MACHINE, by Messrs. W. F. Thomas & Co.

a picker. The baster-plate has been abandoned for the top four-motion feed, and the general arrangement of the moving parts has undergone a complete transformation, the essential features of Howe's invention being nevertheless retained (fig. 66).

Messrs. Guinness & Co. exhibit a simple and well-made shuttle machine, which works equally well whichever way it is driven, the work being fed either towards or from the operator at will. In some cases, as, for example, when a zigzag line of stitches is to be produced, or sharp angles turned, this property will be found advantageous. There is another advantage in the facility afforded for securing the seam effectually at any part,—by making a stitch or two in the reverse direction. In this machine, all cams are dispensed with, and replaced by revolving crank-pins. The needle is straight and is fitted to a needle-arm direct, but this arm, in place of oscillating on a fixed centre and describing an arc of a circle, slides vertically in guides within the rear portion of the usual fixed bracket. A link connects the rear end of the needle-arm with a crank-pin on the end of the driving-shaft, which works in bearings immediately under the table or cloth-

plate. The advantages of the straight needle are thus obtained without the disadvantages generally attendant on it,—of the oil employed to lubricate the needle-slide running occasionally down the needle itself and dropping on to and soiling the work,—for the lubricated parts of the slide are entirely out of the way of the work at the back part of the machine. An ingenious and simple modification of the under four-motion feed is employed, consisting of a vertical bar having a slot formed longitudinally therein, and through which a vertically adjustable fulcrum or stud-pin is passed. The upper surface of the bar which acts upon the fabric is made smooth when delicate materials are to be stitched, as it is said that a serrated surface is likely to injure the fabric, whilst with a smooth surface sufficient friction is obtained between the pressure-foot and the feeding surface, to give the necessary propulsion to the fabric without injuring it in any way. The lower end of the vertical-slotted feeding-bar is connected directly to a crank-pin of small throw, on the extreme front end of the driving-spindle. The throw of this crank-pin is invariable; but, by altering the distance between the crank-pin and the fulcrum on which the bar vibrates, the lateral throw of the upper end of the feeding-bar, and consequently the length of the stitch, can be varied to any desired extent. The vertical or rising-and-falling motion of the feeder, is obtained direct from the crank-pin, and is equal to the throw of the crank. The nose or point of the shuttle is situated above its longitudinal axis, and close under the cloth-plate: consequently the vertical travel of the needle may be reduced; for, so long as the eye of the needle passes below the point of the shuttle, the loop will be caught and expanded sufficiently for the shuttle to pass through. This construction of shuttle facilitates the use of shuttles of various sizes in the same machine, without varying the stroke of the needle, provided the points of the different shuttles are situated at the same level below the cloth-plate. In lieu of the usual shuttle-race or groove for the shuttle to run in, a shuttle-holder or carriage is employed, which carries the shuttle and travels to and fro along a horizontal guiding spindle. This shuttle-holder or carrier is connected by a short link with a crank-pin near the front end of the driving-spindle. As all the three crank-pins for working the needle, the shuttle, and the feed, respectively, are disposed so as to be on their dead centres at the same time, it matters not in which direction they are rotated, the only change of motion being in the feeding-bar. A great variety of ornamental or fancy stitches may be produced in this machine from three threads, by using two parallel needles placed side by side in the line of the seam and carried by the same needle-bar, and by varying the length of stitch so as to cause it to be greater or less than the distance between the needles, or by changing the direction of the feed. The slack of the needle-thread is taken up and the stitches tightened by

small auxiliary lever-arms actuated by the needle-slide itself.

Messrs. M'Kenzie & Co., Glasgow, exhibit some well-made shuttle-machines for manufacturing purposes, in which a crank-motion is used for driving the shuttles. The substitution of cranks for cams, where practicable, in sewing machines, is a step in the right direction, and several makers now avail themselves of this method of obtaining the movements required. The throw of a crank never varies, but the motion derived from a cam is materially deranged by a little wear on the cam-surfaces, and, the moving parts no longer keeping time with each other, the machine becomes useless. Messrs. M'Kenzie & Co.'s machines are provided with straight needles, and the under four-motion feed, which is arranged to feed in two different directions at right angles to each other, by a very simple adjustment of the feeding mechanism. The screw which regulates the length of the stitch, is more easily got at than in most other machines; it is placed upon the surface of, and not underneath, the cloth-plate.

Messrs. R. E. Simpson & Co., Glasgow, exhibited several shuttle machines for manufacturing purposes and family use, in which cranks are employed entirely in substitution for cams. The needle is straight, and the feed is the under four-motion variety, the rising and falling motion of the serrated bar being derived from an incline on the shuttle-driver. A duplex feed, somewhat similar to, but not so convenient as, M'Kenzie's, is fitted to the cylinder or tube machines. Their Davenport machine is intended to meet the requirements of the boudoir, being enclosed in a ladies' writing-desk, which is thus made to serve the double purpose of a sewing-machine case, and a useful article of furniture.

Messrs. Bradbury & Co., Oldham, exhibited M'Crossan's "Empire" sewing machine, in which cams are entirely dispensed with, an ingenious arrangement of cranks being employed for giving a differential motion to a straight needle. On one end of a short driving-spindle is fitted a disc, provided with a crank-pin, and this pin is coupled by a short link to a second crank-pin in a disc on the near end of a spindle, the axial line of which is slightly eccentric to the first motion-shaft. To the front end of this last-mentioned spindle another disc and crank-pin are fitted, which transmit an up-and-down motion by means of a connecting rod to the vertical needle-slide. An alternately quick and slow motion is thus imparted to the needle, the rising of the needle being performed more rapidly than its descent, and when at its lowest position, it makes a pause or dwell, to allow the shuttle time to enter and pass through the loop of the needle-thread.

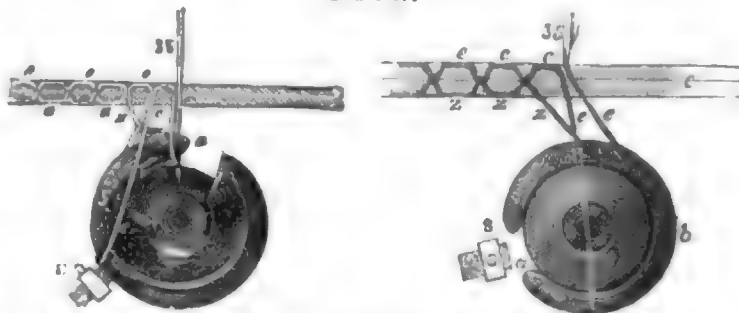
CHAPTER III.

LOCK-STITCH MACHINES WITHOUT THE SHUTTLE.

A class of lock-stitch machines was exhibited, producing identically the same stitch as the shuttle machine, by means of a rotating hook, carrying the bobbin for the under thread, in lieu of a travelling shuttle.

Messrs. Wheeler & Wilson's lock-stitch machines attracted general notice for their beauty of finish, and for their easy, rapid, and silent manner of working. There is probably no lock-stitch machine equal to Wheeler & Wilson's for family use, or for comparatively light manufacturing purposes, such as dress and mantle making. The lower bobbin is almost a fac-simile of the bobbin long used in lace-making machines, the thread being wound upon an axis between two thin metal discs of about one inch in diameter. It is fitted loosely inside a recess in the front of a rotating circular hook fast on the front end of the driving-spindle, which works immediately beneath the table or cloth-plate of the machine. An adjustable ring-shaped holder or bracket serves to retain the bobbin, whilst it allows it sufficient play in its recess to admit of the loop

FIGS. 67.



ROTATING HOOK of Messrs. Wheeler & Wilson's Sewing Machine.

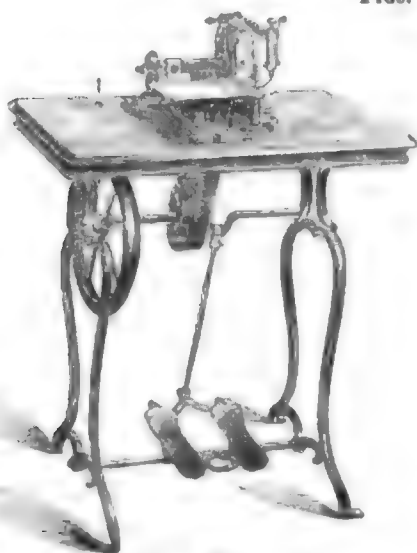
of the needle-thread passing freely between the bobbin and its supporting surface (figs. 67). The needle, which has an eye near the point, is attached directly to the end of a vibrating lever actuated by an eccentric on the driving-spindle; and it is curved to conform to the arc described by the end of the lever. The tension for the needle-thread is obtained by passing the thread once round the periphery of a small grooved pulley, which turns loosely on a fixed stud-centre, and is pressed against by a spring and adjusting nut. The under "four-motion feed" is adapted to these machines. In the operation of sewing, the loops of the needle-thread are caught and extended by the revolving hook, and passed under the bobbin so as to interlock the two threads; the loops are retained by a "loop-check" until the loop of the succeeding stitch is being extended, which has the effect of drawing up and tightening the previous loop just cast off. Only one special tension apparatus is required, namely, that for the needle-thread, there being no need of tension for the under thread, as a sufficient strain is maintained upon

it by the tendency of the bobbin to rotate with the hook. The saving of a tensional apparatus for the lower thread is a material advantage in favour of this machine, as it leaves but one to

Mr. H. Ferrabee, London, exhibited the "British Sewing Machine," which resembles, in some respects, Messrs. Wheeler & Wilson's lock-stitch machine, having the stationary bobbin and the revolving hook. The hook is of a much more simple construction than the other, and it operates in a slightly different manner. An upright rocking lever, linked at its lower end to the bed-plate, is rocked by a crank-pin on the driving-shaft, working in the centre of the lever. A hook at the upper end of the lever travels, in virtue of the motion so communicated to the lever, in an elliptical path round the shuttle, and carries with it the loop of the needle-thread, which it casts off before completing its circuit.

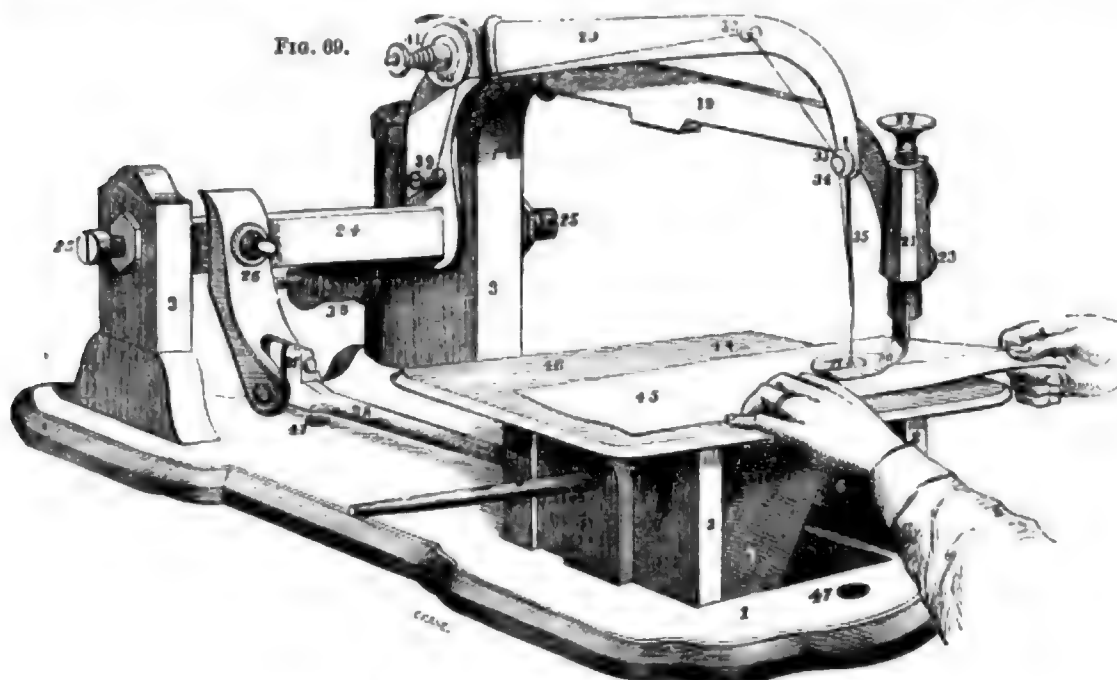
Mr. S. C. Salisbury, London, exhibited some well-made lock-stitch machines curiously constructed. In one of these machines, the filling thread is contained in a thread-case of a sufficient size to receive an

FIGS. 68.

*Large Machine.**Cylinder Machine.*

SEWING MACHINES, by Messrs. Wheeler & Wilson.

look after,—on the upper thread. The art of properly regulating the tensional apparatus in all sewing machines, is the most difficult lesson to be learned by the operator (figs. 68, 69).



SEWING MACHINE, by Messrs. Wheeler & Wilson; with Crystal Cloth Presser.

ordinary reel or cotton bobbin, and consequently the trouble of spooling or filling the shuttle attendant upon all other lock-stitch machines is here obviated. A small hook on the end of this thread-case serves to catch the loop of the needle-thread, and expand it sufficiently for the thread-case to pass easily through it. For this purpose, a partial rotatory, as well as a longitudinal reciprocating motion, is imparted to the thread-case. The stitch produced is the variety of lock-stitch known as "knot-stitch," the loop of the

needle-thread receiving a "kink" or twist before being interlocked with the filling-thread. The needle employed is the ordinary sewing-machine needle, and the cloth is propelled by a top four-motion feed, in which a positive lift and throw is given by separate cams for that purpose.

There remain to be noticed the chain-stitch sewing machines, which may be described generally as looping machines, since they produce their stitches by interlooping a single thread with itself or with a second thread. The second thread,

when used, is also interlooped with the first, whilst, in the lock-stitch, the second thread is passed singly through each loop of the needle-thread. The stitches of all looping machines are capable of being unravelled if the proper end of the thread be drawn upon.

CHAPTER IV.

SINGLE-THREAD CHAIN-STITCH SEWING MACHINES.

The single-thread looping machine was invented upwards of twelve years ago by Mr. Morey, of the United States, and appears to have been subsequently re-invented, in 1857, by Mr. Gibbs, a farmer of Millpoint, amongst the mountains of Virginia, who had never seen a sewing machine before. Mr. James Wilcox added several improvements, which, combined with Mr. Gibbs's ideas, have resulted in one of the simplest, fastest, and least noisy sewing machines. It is therefore particularly suited to family use. The stitch produced in this machine is a twisted chain or tambour stitch, which is said to be more secure than the common chain-stitch. In the ordinary chain-stitch, the needle carries a loop of thread through the fabric, which is retained until the succeeding loop is formed,—this second loop being passed through the fabric and through the preceding loop, and so on. But in the twisted chain-stitch, the first loop, when formed, receives a half turn or twist before the second loop is brought through it. As the stability of a seam depends entirely upon the amount of friction or bind which the thread has upon itself and upon the fabric, it follows that the more closely the loops of thread are interwound or locked with each other, and with the fabric, by twisting or otherwise, the more secure is the seam against the ripping asunder of the parts united. But the single-thread stitch is liable to be unravelled: that is to say, if the proper end of the thread be first discovered and unfastened, the stitches can be pulled out with the greatest ease, and consequently a great objection has always been raised to single-thread chain-stitch machines. The seam, nevertheless, if perfectly made—that is to say, without a false or slipped stitch,—will answer sufficiently well for ordinary family purposes. Indeed, in family sewing machines, the capability of unravelling a seam when desired is rather an advantage than otherwise, for work sometimes requires to be unpicked. The stitch-forming instruments in Messrs. Wilcox & Gibbs's machine, are a straight eye-pointed needle and a revolving hooked looper. The cloth is propelled by an under four-motion feed in conjunction with a spring pressure-foot. The tension for the thread is obtained by nipping it, more or less, between two glass discs as it passes off from the bobbin. The hooked looper is the leading feature of the machine; it consists of

two hooks united back to back, with their points in opposite directions, and a projecting arm or spur, the axis of rotation being at the junction of the "spur" with the stem of the double hook. This looper is carried on the front end of the driving-spindle, and rotates constantly, in one direction, immediately beneath the table or cloth-plate of the machine. The needle is fixed in a vertical slide actuated by a lever which receives a vertical reciprocating motion from an eccentric on the driving-spindle. The front end of the driving-spindle is provided with a crank-pin which rotates in a slot in the feeding-bar, and imparts not only the vertical movements to it, but also a horizontal motion. In producing the stitch, the needle first carries a loop down through the fabric; this loop is caught and extended by the front point of the rotating looper, and receives a half twist by the action of the spur, which causes the back portion of the loop to be brought to the front, and *vice versa*. By the time the loop has received the twist, the needle has been withdrawn, and the cloth advanced one stitch, when the needle again descends, and the point of the hook takes the second loop and draws it through the preceding one, which has in the meantime been twisted and slipped into the thread of the rear hook, from which it is finally cast off and drawn up to the under surface of the fabric. The tightening and drawing up of each stitch is effected by the extension of the succeeding loop, and the onward movement of the fabric combined. By employing a second or reverse hook to receive the loop after it has been cast off from the front hook, and before it is finally drawn up to the fabric, the tendency to kinking or entanglement of the loop as it is being tightened is obviated, since it is not finally released until it is almost entirely drawn up.

Mr. Bigelow, United States, exhibited two excellent machines, the invention of Mr. L. R. Blake, for heavy leather-stitching,—as, for example, stitching the soles on to the uppers of boots and shoes, and making harness. In heavy leather work, a waxed thread is required, and hence leather-stitching machines are generally known as "waxed-thread machines." The stitch employed is usually the chain-stitch, which is produced in the same manner as ladies' crochet work, by passing a hook through the material, placing the thread in the throat of the hook, and carrying a loop of the thread through the material in withdrawing the hook, the loop being also drawn through the previously formed loop so as to interchain the several loops one with another. In Blake's machine, the boot or shoe, having the outer sole tacked into its place, is fitted on to the end of a "horn" or fixed arm rising at a slight angle from the bed-plate. The extremity of this horn is sufficiently reduced to enter the most confined parts of the interior of the shoe between the edge of the inner sole and the uppers. A thread carrier or "whirl," having a circular reciprocating motion,

is contained within the small end of the "horn," the waxed thread being passed through a hole made eccentrically to the vertical axis of rotation of the "whirl." The hook, on descending, enters an opening made in the centre of the "whirl," and the latter, as it rotates, passes the thread round the stem of the hook, causing it to enter the throat of the hook, when it is caught and drawn up through the thicknesses of leather to be stitched. The shoe is traversed by a species of top four-motion feed, consisting of a pointed finger instead of the usual serrated plate, and this finger may be guided by hand to propel the shoe in the desired course corresponding to the contour of the sole.

In the second machine, the feeder acts always in the same direction, and the shoe is carried on a rotating "horn," so that it may be guided by the operator in the direction desired. Machines of this kind are employed in making boots and shoes for the Federal armies, and are each capable of stitching 150 pairs a day.

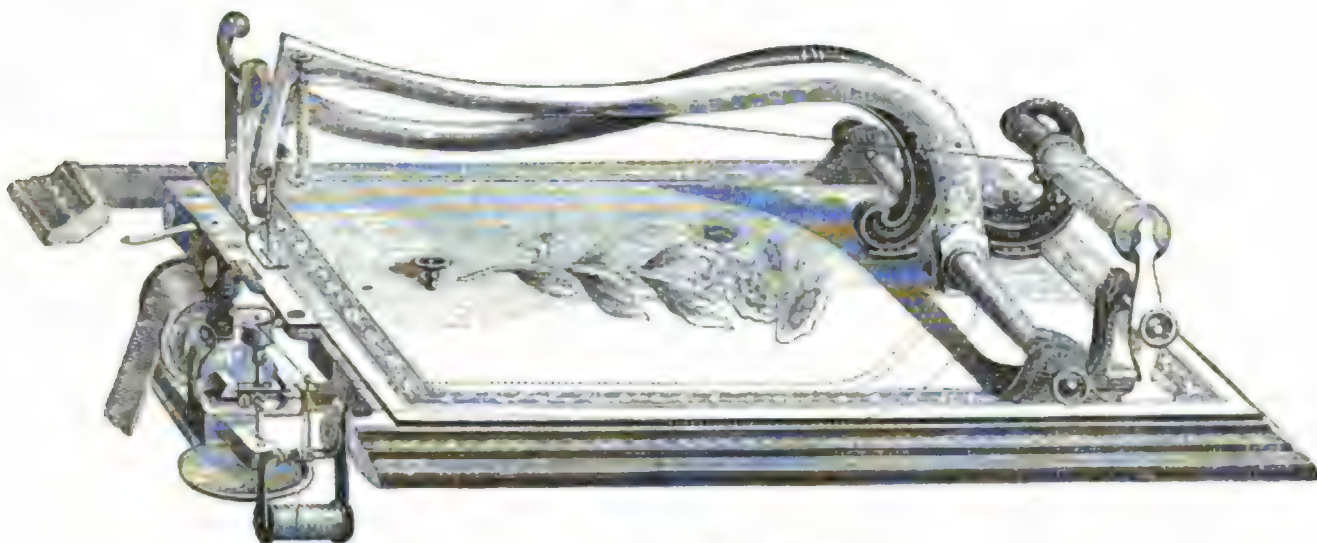
CHAPTER V.

DOUBLE-THREAD CHAIN-STITCH SEWING MACHINES.

Messrs. Newton Wilson & Co. exhibited some well-made double-thread chain-stitch sewing machines, and a few shuttle machines of a novel construction, contributed from the Grover & Baker Sewing Machine Company's establishment at Boston, U.S.

The Grover & Baker looping or double-thread chain-stitch machine was introduced into England in 1852; since that time, it has been considerably improved and modified. In the heavier machine made for manufacturing purposes, a straight needle is used, the slide or carrier of which is actuated by a vibrating bell-crank lever driven by a cam underneath the table or cloth-plate. In the lighter descriptions, the needle-slide is dispensed with, the needle being curved and attached direct to the end of the

FIG. 70.



SEWING MACHINE, by Messrs. Newton Wilson & Co.

vibrating needle-lever. This lever is shaped thus, : one limb vibrating above and the other beneath the table on a fulcrum at the bend. The lower limb has a slotted steel plate fitted to its front end, which has a reciprocating vertical motion along a spiral stem carrying a curvilinear-looper shaped somewhat similar to a ram's horn, and operating with a circular reciprocating motion in a horizontal plane immediately beneath the cloth-plate. This looper has an eye near its point and a second eye at the heel of the bend, the portion between the two eyes being grooved to receive the under thread supplied from a spool placed under the machine. In some cases, as in the heavier machines, the looper is actuated by a segmental rack gearing into a pinion on the vertical axis of the looper. The family machines are driven by a crank on one end of a short driving-shaft, the crank-pin working in a slot in the front end of the lower limb of the needle-

lever. The needle is supplied with thread from a bobbin on the top of the machine, in the usual manner, whilst the thread for the looper is passed first through the eye at the heel of the bend, and then through the eye near its point, the thread lying in the groove in the periphery of the looper between the two eyes. The cloth is propelled by the under four-motion feed (fig. 70).

The needle first carries a loop of its thread through the fabric and through a loop of the under thread, which is presented to it by the looper. The curvilinear shape of this instrument, and the fact of its thread being carried on its periphery, ensure the presentation of the under-thread in the form of an open or expanded loop to the needle, which always passes inside of or within the bend of the looper. As the needle descends, the looper recedes in a circular direction, and by the time the needle has completed

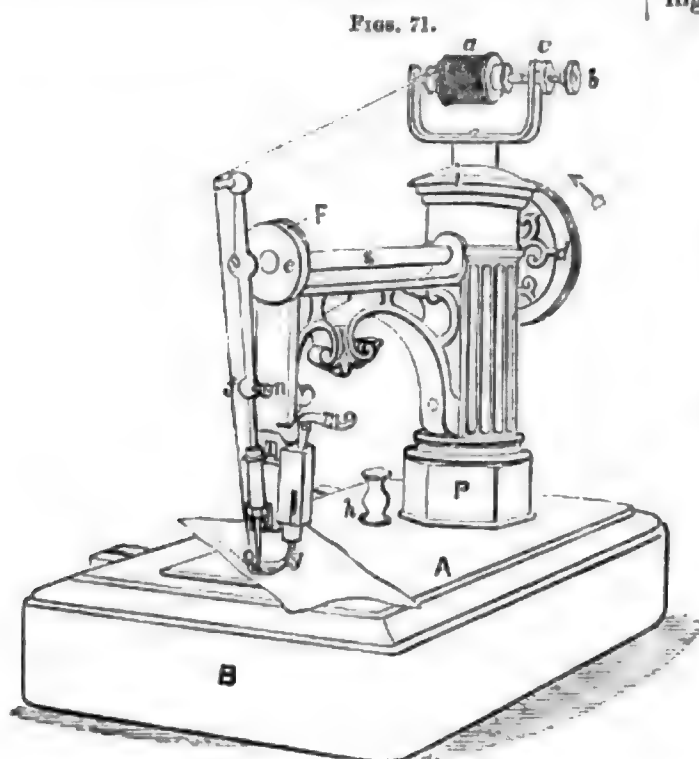
its downward stroke, the looper has left a loop of its thread round the stem of the needle so as to encircle the loop of the needle-thread; as the needle ascends, and before its eye has passed above the point of the looper, the latter returns, and the loop of the needle-thread having been

of the under-thread which was passed through the preceding loop of the needle-thread, and so on, the two threads being interlooped but not interlocked with each other.

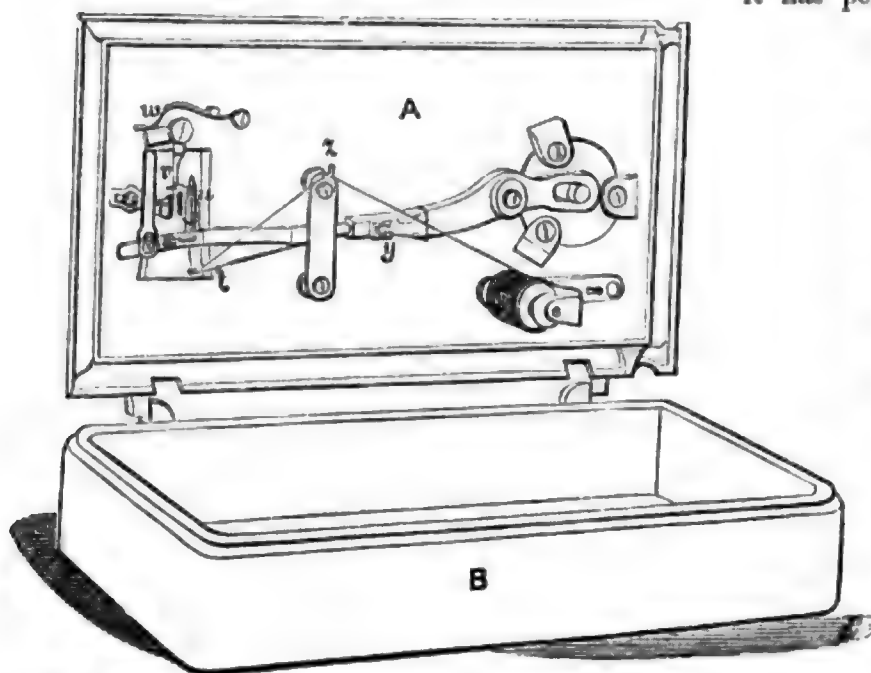
This stitch is suitable either for ordinary sewing or for embroidering, as, for example, where a braiding effect is desired. In this case, it is necessary to use a thicker under-thread, when a raised cord or braid will be produced on one side of the work, whilst the other side presents the appearance of ordinary stitching. The varied display of well-executed stitching and embroidery produced on the Grover & Baker machine, in the Process Court of the Exhibition, reflected great credit on the fair machinist, Mrs. Rogers, of California, who is said to be one of the cleverest experts in machine-sewing of the present day.

Messrs. Whight & Mann exhibited a simple form of machine for producing the double-loop, or Grover & Baker stitch. A straight needle is used in combination with a straight looper, but the chief peculiarity consists in the mode of propelling the cloth. The needle-bar receives its vertical motion from a crank-pin on the end of the driving-shaft, the needle at the lower end being guided and stayed by a swivelling socket, on which it oscillates. The lateral motion of the needle is made to do duty in propelling or dragging onwards the fabric after it has penetrated it. This machine is capable of executing fine work (figs. 71).

Mr. H. Hughes, Homerton, exhibited chain-goffering machines, for goffering or fluting two or more pieces of lace or ribbon, to connect the pieces together, and emboss or indent them, if required, in the same machine, and in one operation. Two sets of pattern-formers are carried on an endless chain, the lower set fluting one side, and the upper set fluting the other side, of the pieces. The pieces are then joined at the middle by a gummed cotton thread, from a bobbin, and are turned out as a ruche or cap-front.



Machine Ready for work.



Bed-plate turned up, to show the parts beneath, giving motion to the lower needle or looper.

SEWING MACHINE, by Messrs. Whight & Mann.

opened or caused to buckle outwards by the ordinary friction of the cloth against the thread, the point of the looper enters the needle-thread and passes a loop of the under-thread through it. The cloth then moves forward, and the needle again descends and passes through the open loop

CHAPTER VI.

FOREIGN SEWING MACHINES.

The foreign sewing machines exhibited were, for the most part, copies of well-known American machines.

FRANCE.—M. Callebaut, Paris, exhibited several modifications of shuttle sewing machines for family and manufacturing purposes, constructed on the Singer type. He exhibited, also, three ingeniously-contrived glove-stitching machines, for producing the "whip" or over-cast stitch. M. Callebaut's improvements refer chiefly to the feeding devices for back-stitching, herring-bone stitch, and zigzag or vandyke stitching. Each machine is provided with a regulating handle, by means of which the feed may be changed from a straight to a zigzag or other motion without stopping the machine. One lock-stitch machine, for sewing the seams of umbrellas and parasols, and for sewing hosiery goods, produced a very elastic stitch by the aid of a top four-motion feed, so contrived as to carry the work a half-stitch back for every stitch it is moved forward. The result is a species of lock-stitch, like hand-made back-stitching. In the "herring-bone stitch" machine, a zigzag motion is imparted to the feeding foot, so that the stitches succeed each other in a zigzag direction. To increase the security of the ordinary lock-stitch, a device for reversing the feeding-wheel at any desired part of the seam is applied to one of the machines, which enables the operator to make any number of stitches back upon the seam. In this machine, which is extensively employed in the Prussian, Russian, and French armies for making soldiers' clothing, the shuttle is considerably larger than usual, and consequently holds more thread; thus saving the time otherwise lost in repeatedly filling or rewinding the shuttle-spool. Amongst the heavier class of machines for leather work, &c., an ingenious cylinder machine for boot and shoe work is worthy of notice for its duplex feed-motion. The feed employed is the under four-motion variety; but, by a slight adjustment of a regulator, and without stopping the machine, the work may be propelled either longitudinally or laterally. Provision is made for employing two needles in the same slide, placed in a line transverse to the direction of the feed. The shuttle-thread is passed through the loops of both the needle-threads, and consequently lies in a zigzag direction on one side of the work; whilst, on the other side, two parallel seams of the ordinary appearance are presented. An extra heavy leather machine for harness work is also exhibited, in which the wheel-feed is used in combination with a reciprocating and rising and falling pressure-foot, to give a better hold upon the work. Provision is also made for introducing at will a few back-stitches, for the purpose of securing the seam at any part, and for fastening off at the end of a seam.

The glove machines are constructed on an entirely different principle from that of the ordinary sewing machine. The work, in one design, is held between the jaws of a pair of

travelling clamps, which are notched or indented on their holding edge to serve as guides for the sewing instrument. The clamps require to be readjusted when they have travelled their whole length. The sewing instrument consists of a hook working in a horizontal direction, and drawing the thread through the material from the outer to the inner side. The thread is not supplied continuously from a bobbin, but is used in detached lengths; and when entirely worked up, a fresh needful or length must be supplied. As fast as the hook draws the thread through the material, a finger, or thread-carrier, takes a portion of the thread, and passes it over the edge of the front side again, where it is caught by the hook as before, and is again drawn through. In another machine, a wheel-feed arrangement is substituted for the travelling clamps, and the sewing may be proceeded with continuously.

M. de Celles, Paris, exhibited a curious lock-stitch machine, of American origin, having the property of forming a perfect knot, like a weaver's knot, in the shuttle-thread, at each stitch. If the knot be not tied close into the material, it does more harm than good, by preventing the proper tightening of the stitch, as there is no slip in it when once made.

M. Le Blond, Paris, exhibited some good specimens of workmanship. The machines are of a compound order, for the production of three different kinds of stitches—viz., the lock-stitch, the double-thread loop or knotted stitch, and the single-thread chain or tambour stitch.

AUSTRIA.—M. J. Warchalovsky, Vienna, exhibited two machines—one a shuttle-stitch, and the other a single-thread chain-stitch machine. They were provided with duplicate sets of sewing instruments, to work simultaneously, and consequently to produce two seams at the same time. The looping or chain-stitch machine is the same as one patented in England by Mr. F. N. Parker, in 1859, in which a vibrating hook is employed for holding the loop and presenting it to the needle at its next descent.

HESSE-CASSEL.—M. J. Schröder, Darmstadt, exhibited three machines, two of which were double-thread loop-stitch machines, of the Grover & Baker pattern, and the third was a compound of the Singer and the Grover & Baker improved shuttle machine.

BELGIUM.—M. A. Le Roy, Brussels, exhibited a machine for stitching button-holes, in company with a large assortment of other kinds of sewing machines.

PRUSSIA.—M. F. Bücke, Berlin, exhibited a large collection of sewing machines, copies of different American machines.

III.—MANUFACTURING MACHINES AND TOOLS FOR WORKING IN IRON, WOOD, AND OTHER MATERIALS.

SECTION I.

MACHINE-TOOLS, ETC., FOR WORKING IN IRON.

CHAPTER I.

INTRODUCTION.

THE lead originally taken by Messrs. Joseph Whitworth & Co., in the design and the manufacture of machine-tools, has told beneficially upon the general advancement of this branch of machine engineering. Mr. Whitworth, about five-and-twenty years ago, established his reputation as a practical man of superior principles, of enlarged views, and of fine taste, who aimed at nothing short of absolute constructive perfection. That he succeeded in compassing, within the nearest attainable limit, the high standard he set up for himself, and in exciting the emulation of others, is a matter of history, of which ample evidence was furnished by the display of tools and other machinery in the Western Annex. Not only in the special department of machine-tools was the beneficial influence of Mr. Whitworth's example manifested; his elevated style of treatment pervaded the works of engineers in other departments of mechanical construction. The scraped plane surface, adopted at Mr. Whitworth's establishment about twenty-five years ago, was noticeable everywhere. To appreciate rightly the importance and value of the method of scraping for obtaining true surfaces, it is necessary to revert for a moment to the antecedent process of grinding with emery. If a ground surface be examined, the bearing points will be found lying together in irregular masses, with extensive cavities intervening; and this defect is not under the control of the operator. A portion of the emery used for grinding becomes fixed in the pores of the metal, and causes a rapid and irregular wear of the surfaces. As grinding for a true surface is, in a manner, a self-acting process, it blunts the sense of responsibility in the operative, and he slurs it over. So, at one time, the practice of grinding altogether impeded the progress of improvement in construction. "A true surface,"

said Mr. Whitworth, in 1840, "instead of being, as it ought to be, in common use, is almost unknown; few mechanics have any distinct knowledge of the method to be pursued for obtaining it; nor do practical men sufficiently advert, either to the immense importance, or to the comparative facility, of the acquisition." And he spoke like a true prophet when he maintained, at the same time, that "a higher standard of excellence would be gradually established, the influence of which would be felt throughout all mechanical operations."*

Next to the true plane, the power of measurement is the second great element in constructive mechanics, insisted on by Mr. Whitworth. "The latter," he said, in 1856, "cannot be attained without the former, which is therefore," as is now universally acknowledged, "of primary importance." Mr. Whitworth exhibited, at the meeting in 1856 referred to in the footnote, a small machine, by which a difference in length or thickness of the one-millionth part of an inch is detected. "The principle," he says, "is that of employing the sense of touch instead of sight"—an admirable and forcible distinction. "If an object be placed between two parallel true planes, adjusted so that the hand can just feel them in contact, you will find, on moving the planes only the fifty-thousandth of an inch nearer together, that the object is distinctly tighter, requiring greater force to move it between them." If, again, a thin bar be brought into contact between the two planes, so as just to allow it, on being raised, to fall by its gravity, it will be found that by bringing the planes into closer contact by even the one-millionth of an inch, the thin bar will be suspended—friction overcoming its gravity. In the manufacture of his standard gauges of size, Mr. Whitworth's

* "On Plane Metallic Surfaces, and the proper method of preparing them;" a paper read by Mr. Whitworth at the Meeting of the British Association at Glasgow, in 1840; and referred to in his Address at the Meeting of the Institution of Mechanical Engineers, at Glasgow, in 1856.

workmen measure to the twenty-thousandth of an inch, and, strange as it may seem, these measures are as familiar and appreciable as those of any larger dimensions. As a matter of necessity, argues Mr. Whitworth, the only scale of measurement that can be used for such small sizes, and proportionately small differences, must be a decimal one; any other would be productive of endless confusion and insurmountable difficulties. "What exact notion," he fairly asks, "can any man have of such a size as 'a bare sixteenth,' or 'a full thirty-second?'"

But, in connection with the duplicate system of the true plane and the power of measurement, there is the uniform system of screw-threads, also introduced by Mr. Whitworth. Previous to its introduction, great inconvenience arose from the variety of threads adopted by different manufacturers. By the force of its intrinsic merit, the uniform system, initiated nearly thirty years ago, and described before the Institution of Civil Engineers in 1841, is now universally recognized and adopted. The leading datum, applicable to all sizes of angular screws, is the constant angle, 55° , which is adopted for the sides of the threads, by which a constant proportion is established between the depth and the pitch of the thread.

The lathe, and the planing machine, respectively develop the circular and the plane forms; and they are used in the manufacture of all other machines. To obtain perfect steadiness of motion and action, Messrs. Whitworth & Co. introduced the screw as a means of traversing the saddle in the one, and the table in the other. The screw is now universally applied to lathes designed for cutting screws; but other constructors have not in general shared Messrs. Whitworth & Co.'s views of the sufficiency of the screw for all the purposes of a lathe. They contend that a screw for cutting screws, or reproducing itself, should be preserved from the irregular wear incidental to the ordinary work of a lathe, otherwise a true screw will not be produced from it; and they supplement the screw by a rack-and-pinion motion, which is fully adequate for sliding and surfacing operations. The conical bearings for the cone-spindle of the lathe, introduced by Messrs. Whitworth & Co., are frequently adopted by tool-makers, except for lathes of the largest class, in which the cylindrical bearing is retained, offering the steadiest support for overhung masses fixed on the face-plate. In the application of lock-nuts to the cone-spindle, they are placed either on the outside of the headstock, for keeping up the conical bearings without slackness, or on the inside, to take the thrust of the spindle; or, finally, they may be assisted by a tail-pin to take the end thrust, according to the old established usage. Examples of the three modes are exhibited. The application of templates to the lathe, for guiding the cutting-tool in shaping special forms, was exemplified by Messrs. Smith, Beacock, & Tannett. The

duplex or double-cutting lathe of Messrs. Whitworth & Co. continues to be without an imitation amongst the works of other exhibitors, except in the large double face-plate lathes for turning and boring railway wheels. Messrs. Holtzapffel & Co. maintain their long-established supremacy in their peculiar class of work. They exhibited foot-lathes for ornamental turning and amateur work, which are most complete automatic tools for the production of regular forms, simple and complex. By means of ingenious cutting frames, stereographic shapes are described of every variety, from that of a cube to that of an ellipsoid or paraboloid.

In the planing machine, as already observed, Messrs. Whitworth & Co. introduced—and they continue the application of—the screw as a means of traversing the table; and, in addition, the reversing cutter, to cut both ways, whilst the table advances and returns. In the use of the screw and the reversing cutter, Messrs. Whitworth & Co. stand alone. Other exhibitors of planing machines apply the power of the rack and pinion for traversing the table; and, preferring to cut one way only, in the direction for which the cutter-box is fortified by the transverse slide, they have, in some instances, applied two cutter-boxes, to take two cuts simultaneously. In all instances, with one or two exceptions, a quick-return motion is applied to the table, to minimise the delay, and increase the performance.

In the various shaping machines exhibited,—or "universal planing machines," as designated by Mr. Nasmyth, the original designer,—the main features of his first machine are retained, even to the ready method of fastening double-lever eyes, and like work, by means of a spindle and adjustable double-cones. The principal modification of the machine, as now made, was introduced by Messrs. Whitworth & Co., in which the headstock and drill travel over the work, instead of the work traversing under the drill.

Trying back to first principles, Messrs. Whitworth & Co. introduced the method of the hollow, cored, or box casting for the frames of machine-tools, on a principle which may at once be illustrated and enforced by the familiar example of the goose-quill, in which the maximum of strength and stiffness is combined with the minimum consumption of material: the material is removed from the centre and distributed circumferentially, as in a tube or a box, round or square. The capacity of the box casting for resisting strains of every variety—longitudinal, transverse, or torsional—is amazing; and, if it is not the most useful thing those exhibitors have done, it is certainly one of the happiest. The same constructors, in pursuance of the principle of simplicity and directness, have eschewed fragmentary or pieced framework, and, as far as practicable, have cast the lesser upon the larger members. In this matter, as in the construction of hollow framing, other exhibitors have adopted the same practice.

The traversing or slot-drilling machine is a recent machine, introduced by Mr. Nasmyth in 1859, for drilling or sinking slots through pieces of metal, by traversing the drill or the work laterally, in a direction at right angles to the position of the drill. It is a beautiful machine, and whilst it was substantially and successfully worked out by Mr. Nasmyth as a regular engineer's tool, it has been thoroughly developed by Messrs. Sharp, Stewart, & Co., by Messrs. Shanks & Co., and by Messrs. Whitworth & Co. The lateral strain on the drill, whilst making a traversing cut, is the tender point of this machine; and the various modes of meeting that practical difficulty are worthy of study. The success and efficiency of this system of slot-drilling is due to the form of the drill; and it may be added that the form contrived by Mr. Nasmyth for its special service,—namely, a flat-ended drill with the neutral or central portion removed,—has been adopted by other makers.

A new and important application of the vertical drill has been made by Messrs. Beyer, Peacock, & Co., in the frame-drilling machine. It has three drilling heads erected across a movable table, so that with transverse and longitudinal motions, three rows of holes may be drilled at once at any part of the surface of the table.

The application of circular cutters is exemplified in machines for the manufacture of rifle muskets, exhibited by Messrs. Greenwood & Batley. This class of machines has been introduced into this country in a variety of shapes from the Small Arms Factory at Springfield, Massachusetts, U.S. The Americans worked out this problem of interchangeable machine-made muskets some time before it was adopted in England; and, although they have not attained to the degree of nicety which has since been achieved at the Enfield factory, yet they proved the practicability and value of the system. The English Government resolved thoroughly to investigate what was doing in the American armoury, with a view to introduce that mode of manufacturing muskets in England, and to benefit by the progress made in "labour-saving machines" in the States. A commission was accordingly appointed, and sent to America, to investigate the system of manufacture, and also to order some of the most important machines: the result is the fine establishment of machinery at Enfield. When it is remembered that all the parts of a rifle musket are made in perfect duplicate, and that each individual part of a musket may be interchanged with the same part in any other like musket, making an equally good fit; that muskets are manufactured at the rate of two thousand per week; that upwards of seven hundred operations are required for the production of a single rifle, some idea may be formed of the extreme degree of accuracy with which the machines must be employed.

Screwing machinery has received an excellent improvement in the hands of Messrs. Shanks & Co., and of Mr. Sellers, through Messrs. Sharp, Stewart, & Co., in the form of the dies, which are made with conical entrances, cut from the entering threads, to screw a bolt at one cut. The application of chasers for cutting screws, by Messrs. Smith & Coventry, is deserving of notice.

Machinery for cutting files has been for some time on trial, and two machines for that purpose were exhibited. It is doubtful whether the practical difficulties have yet been completely surmounted. All attempts hitherto to introduce such machines into the Sheffield factories have failed from the opposition of workmen.

In punching and shearing machinery, Messrs. M. De Bergue & Co., Barcelona, and Messrs. C. De Bergue & Co., London and Manchester, exhibited, independently, the greatest novelty—the application of a rocking triangular frame, or triplicate lever, for working the punch and the shears. They exhibited also a novel rivet-making machine, which operates by pressure, without a blow. Messrs. D. Cook & Co. exhibited a steam riveting machine, in which the steam-pressure is applied direct to the end of a lever, with an eccentric motion to advance the heading die.

Messrs. James Nasmyth & Co. (of which firm, Mr. Nasmyth was the inventor of the steam-hammer) exhibited a selection of their hammers, and an ingenious dividing and punching machine, for spacing out the rivet-holes precisely to the length of the plate. There were several other exhibitors of steam-hammers,—varieties of the Nasmyth hammer. In one, Condie's hammer, exhibited by Mr. A. C. Wylie, the steam-cylinder constitutes the tup, and is moved up and down, whilst the piston is stationary.

The drawings of a novel and excellent forging press were contributed by Mr. J. Haswell, from Vienna. In this press, the work is forged or shaped by the application of hydraulic pressure, instead of blows.

An efficient machine for forging small bolts, spindles, and other light work, was exhibited by Mr. Ryder, the inventor. Messrs. Whitworth & Co. exhibited a modification of the same machine.

The manufacture of shoes by machinery is receiving great attention; and it is to be presumed that shoemaking by machinery will ere long take its place amongst our other large mechanical industries.

In the following analysis of the machine-tools exhibited, the contributions from Manchester and Leeds are examined first in order, as the head-quarters of the manufacture; and then the machines contributed from other districts.

MANCHESTER MACHINE-TOOLS.

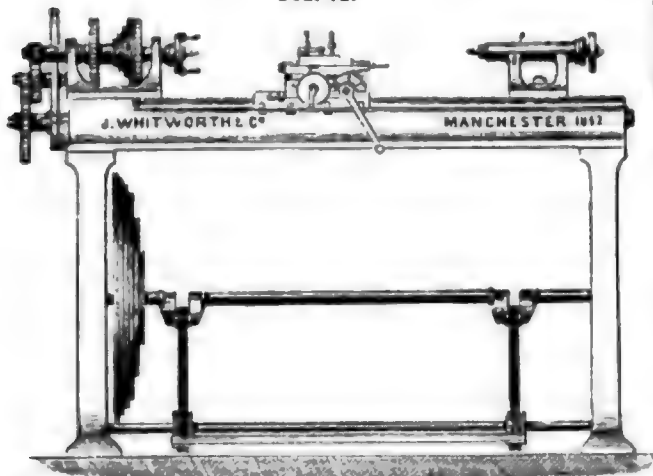
CHAPTER II.

MACHINE-TOOLS, EXHIBITED BY MESSRS.
JOSEPH WHITWORTH AND CO., MANCHESTER.

The extensive and varied collection of tools exhibited by Messrs. Whitworth & Co. were remarkable for tasteful outlines, in combination with strength and scientific design, neat appliances and means of exact adjustment, and perfect workmanship. The collection comprised a selection of lathes, planing machines, slotting and shaping machines, drilling machines, a wheel-cutting machine, a punching and shearing machine, and a forging machine, a screwing machine, screwing tackle, and a case of cylindrical gauges.

1. *Self-acting Foot-Lathe*.—This class of lathe is suited for the use of engineers, amateurs, and

FIG. 72.



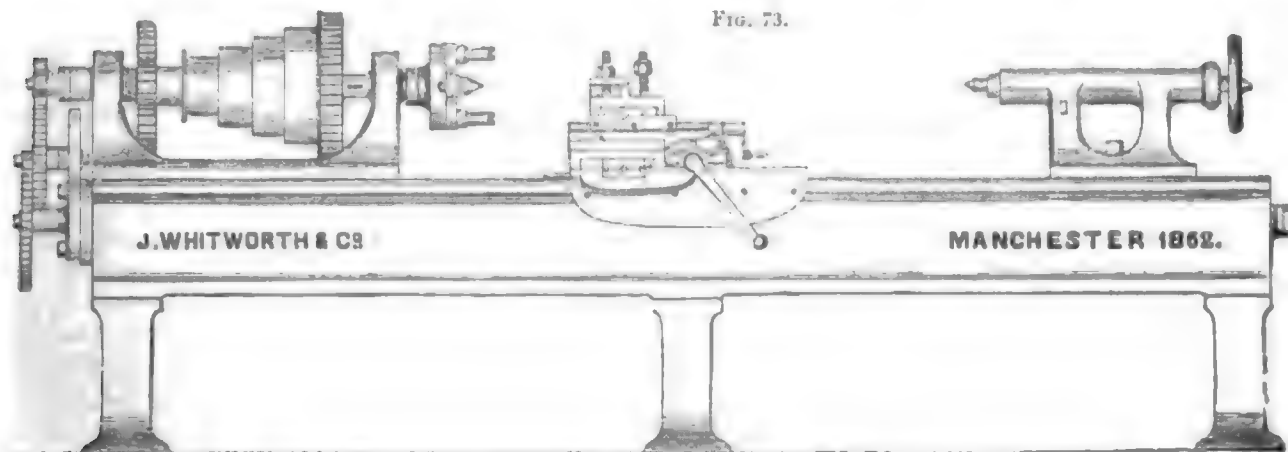
SELF-ACTING FOOT-LATHE, by Messrs. Joseph Whitworth & Co.,
Manchester.

philosophical instrument makers. It is made of several sizes, with from 5 to 9 inches height of centres, and is adapted for turning plain and ornamental work, for small sliding, screw-cutting, and surfacing (fig. 72).

2. *Self-acting Lathe*.—This is a lathe of medium dimensions, with 10-inch centres, and the bed 10 feet in length; it is adapted for sliding, screw-cutting, surfacing, and boring. It is made either with a single cutter, or duplex, with two cutters, facing each other, one on each side of the centre line, which are useful chiefly in sliding or turning shafting, as the work is done more quickly,—the lateral strains of the cutters on the shafting neutralizing each other. The saddle, or carriage, is traversed for sliding or screw-cutting, by means of a screw placed inside the bed of the lathe, reaching from end to end; the screw is also used as a rack for shifting the saddle by hand, by means of a toothed wheel and handle. The cutter may be traversed by hand upon the saddle, longitudinally or transversely. The cone-pulley spindle is formed with steeled conical bearings, to receive the horizontal thrust, and is adjusted by means of a nut and lock-nut placed at the inside as well as the outside of the headstock-frame. The change-wheels for the speeds of screw-cutting are all upon overhung bearings, and wheels of any size may be freely placed upon the spindle (fig. 73).

3. *Self-acting Break-Lathe*.—This lathe has 18-inch heads, and is suitable for sliding, screw-cutting, surfacing, and boring. The bed is movable on the foundation-plate by rack and pinion, so as to form a break or gap for admitting pieces of a large diameter. The foundation-plate is planed and grooved on the whole of its upper surface. The fixed head is made the same height as the shifting head, and is elevated on a separate base or block, bolted to the foundation-plate. A guide-screw is placed inside the shifting bed, and is driven by means of mitre-gearing from the spindle of the fixed head, by a longitudinal shaft passing through the foundation-plate, with spur-gearing at the other extremity. The guide-screw is reversed by means of a reverse mitre wheel on the cone-spindle, which may be put in gear by a clutch. For turning objects of large diameter, the face-plate is driven by a large external spur-wheel bolted to the back of it, driven by a pinion and other gearing from the

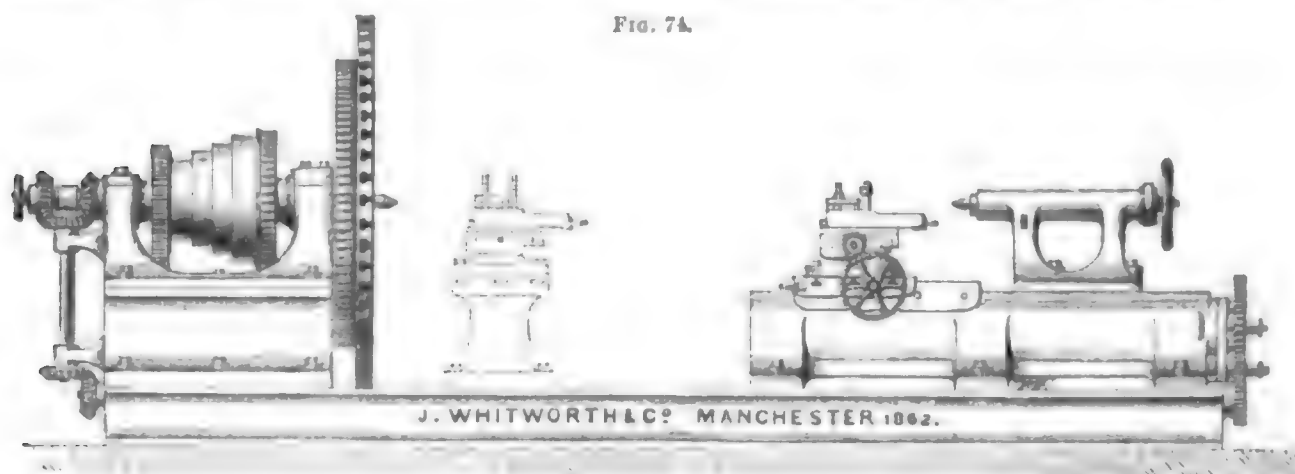
FIG. 73.



SELF-ACTING LATHE, by Messrs. Joseph Whitworth & Co.

cone-pulley. By the substitution of the external spur-wheel for the internal wheel, a greater strength of tooth and diameter of pinion are obtained (fig. 74).

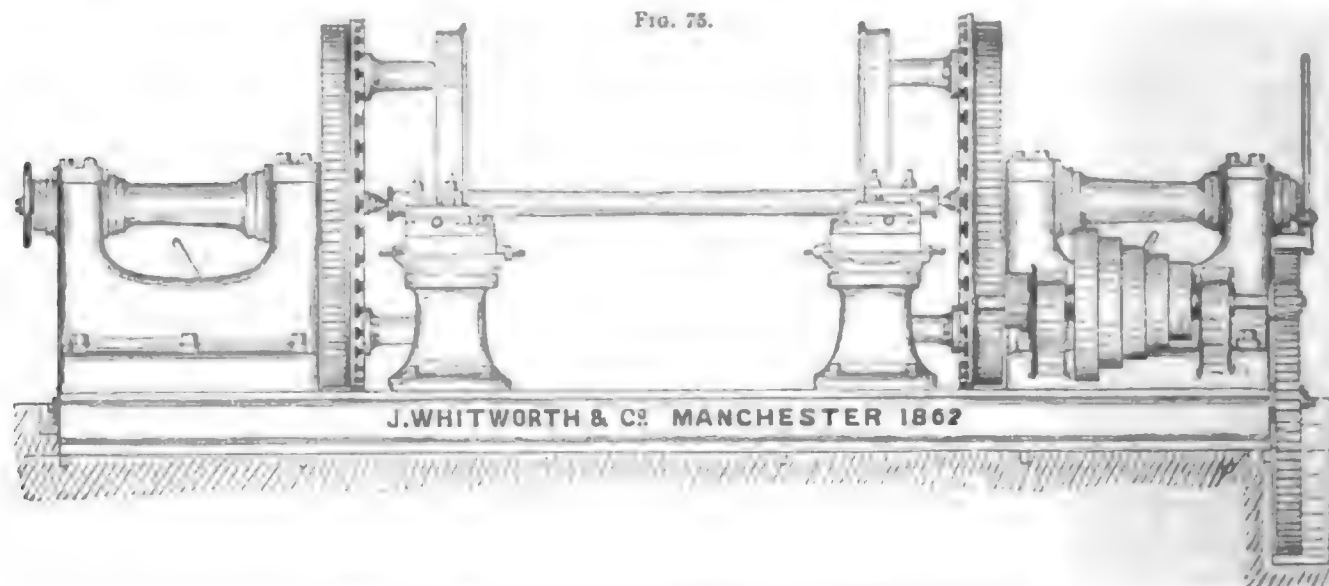
4. *Railway-wheel Turning Lathe*.—The heads of this lathe are 3 feet 3 inches high, each in one piece, instead of being elevated on standards, or separate bases, as in the fixed head of the



SELF-ACTING BREAK-LATHE, by Messrs. Joseph Whitworth & Co.

break-lathe. The lathe is adapted for boring or turning both wheels at once, singly, or on their axles. The cone-pulley is placed at one side of the head, between its bearings, and by means of two spur pinions, one on each end of the cone-spindle, a motion is, in the first place, taken off for turning, through a large spur-wheel on the end of a longitudinal shaft in the foundation-

plate, to drive both face-plates by pinions gearing with large spur-wheels on the backs of them; secondly, for boring wheel-naves, by driving the face-plate on the same head, by the other spur pinion on the cone-pulley shaft, when a much greater speed is required and obtained than for turning. Either or both the face-plates may be engaged for turning, by putting in gear accord-



RAILWAY-WHEEL TURNING-LATHE, by Messrs. Joseph Whitworth & Co.

ingly the pinions on the longitudinal shaft. Self-acting feed-motions are applied to the rests, through over-head connections, worked from the end of the fixed-head spindle by bevil gear (fig. 75).

5. *Self-acting Planing Machines*.—Two self-acting planing machines were exhibited: one of them is 22 feet long, and planes 5 feet 6 inches wide, and 5 feet 6 inches high; it is provided with two reversing cutter-boxes, each to plane both ways. The other machine is of a smaller size, 12 feet long, 3 feet 6 inches wide, and 3 feet 6 inches high; it is provided with one cutter-

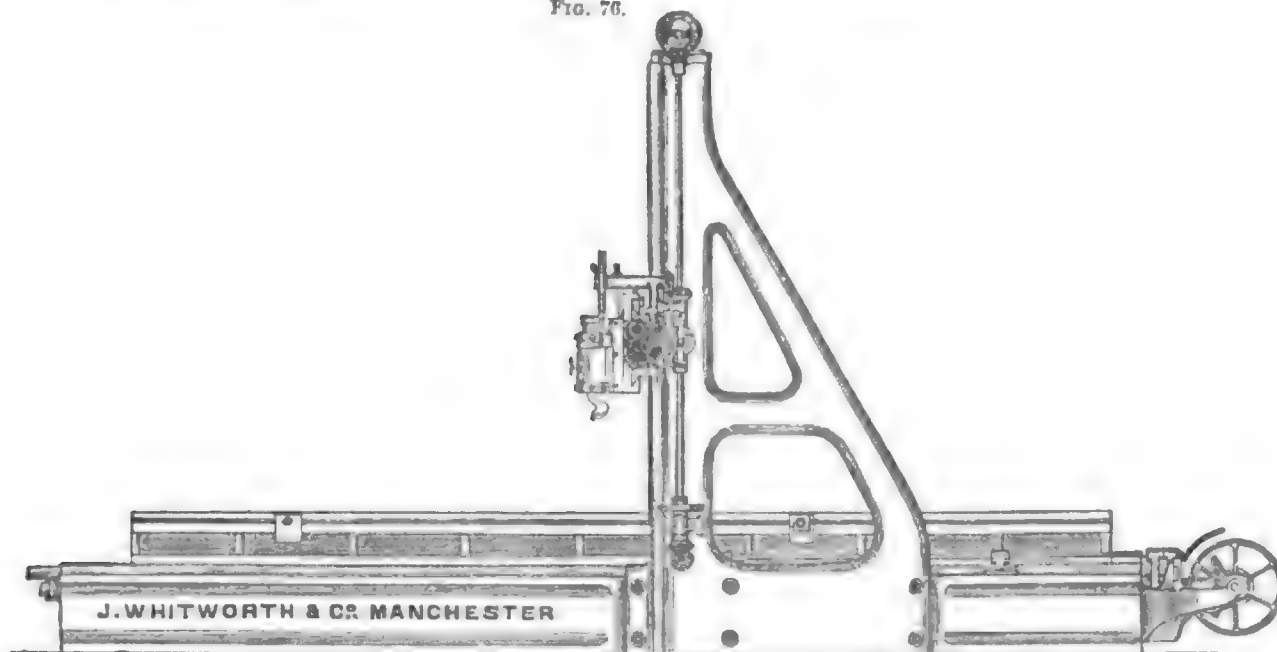
box, and planes only one way, the speed of the return traverse motion of the table being increased, by gearing, to nearly three times the cutting speed forward. The table is, in both cases, moved by a screw, which was originally adopted by the exhibitors, and has always been employed by them in preference to a chain or a rack motion. A vertical shaft is applied at one side of the frame, by means of which the vertical, angular, horizontal, and reversing motions of the cutter-boxes are regulated; and, by the aid of a system of sliding spur-pinions on the end of the cross slide, all or any of the self-acting motions may be put in action at the same time. The

cross slide is elevated by means of the upright shaft, worked below (fig. 76).

A crank-planing machine also was exhibited,

in which the table is worked by a crank and lever, which impart a uniform motion in cutting, and a quick returning motion.

FIG. 76.



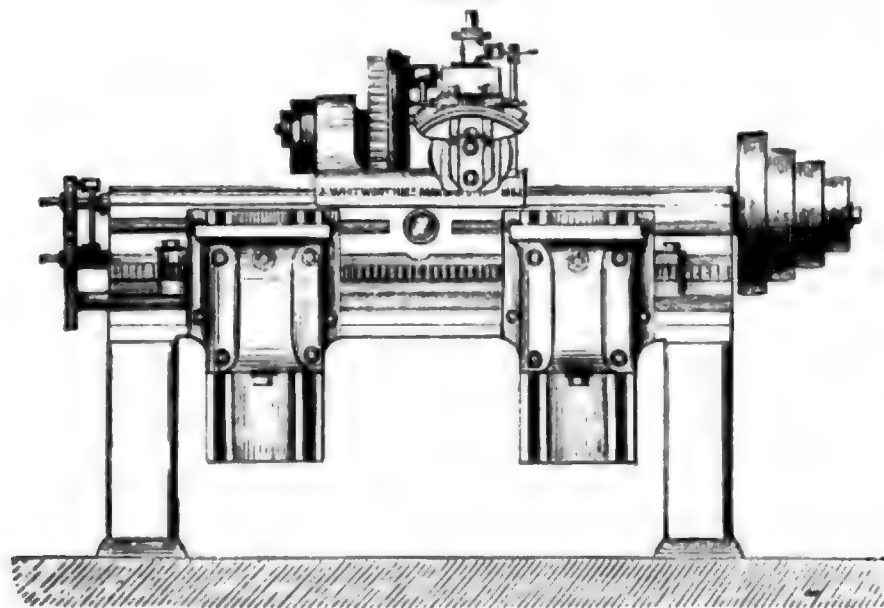
SELF-ACTING PLANING MACHINE, by Messrs. Joseph Whitworth & Co.

6. Universal Shaping Machines.—Two sizes of these machines were exhibited for shaping levers, cranks, connecting rods, and similar work. The ram is moved by means of a peculiar crank-motion, with a quick return, fitted on one side of the driving spur-wheel, and adjustable for any length of stroke or cut. There are self-acting motions for shaping horizontal, vertical, angular,

and pinions; they are attached to the frame in front, by T-headed bolts, sliding in planed grooves.

The larger sizes of this machine are occasionally provided with two headstocks, separately adjustable, and with separate self-acting motions, for which three tables are provided. This arrangement is suitable for planing or shaping both ends of connecting rods at the same time, or for shaping two different objects (fig. 77).

FIG. 77.



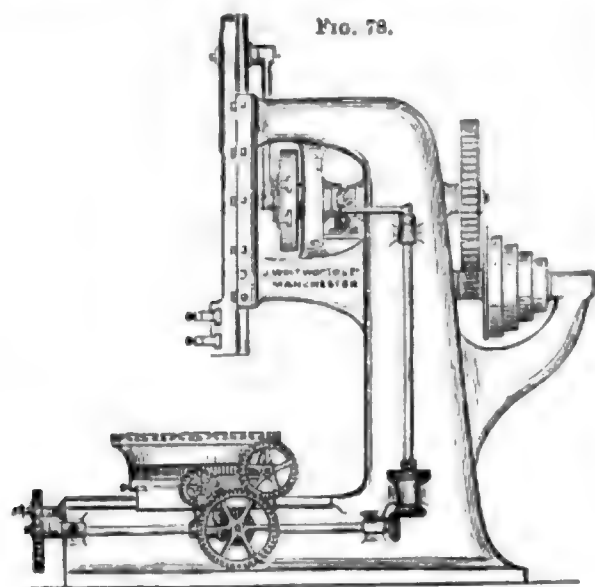
UNIVERSAL SHAPING MACHINE, by Messrs. Joseph Whitworth & Co.

and circular work; and also for hollow curves, the cutter-box being provided with a segment wheel and worm to feed for the hollow-shaping. There are two independent tables for holding the work, adjustable vertically by means of screws and nuts, and longitudinally by means of racks

and pinions; they are attached to the frame in front, by T-headed bolts, sliding in planed grooves. The larger sizes of this machine are occasionally provided with two headstocks, separately adjustable, and with separate self-acting motions, for which three tables are provided. This arrangement is suitable for planing or shaping both ends of connecting rods at the same time, or for shaping two different objects (fig. 77).

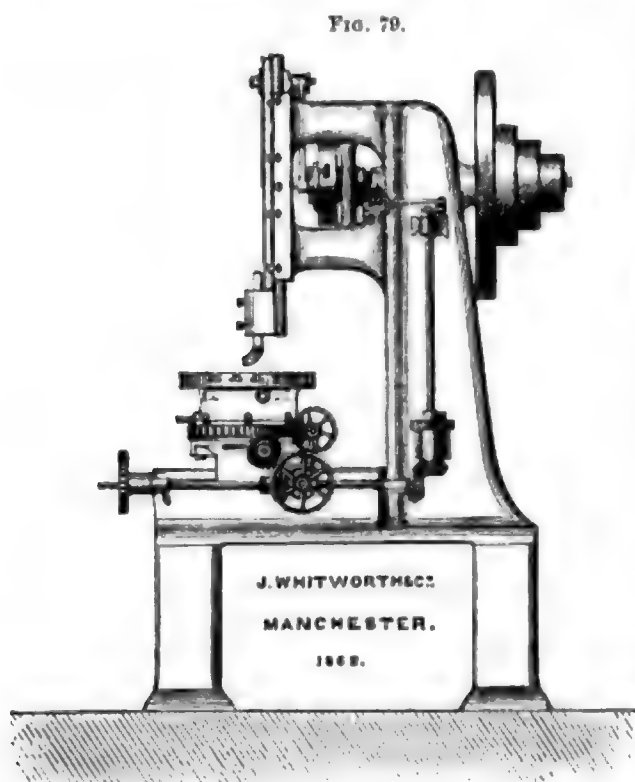
7. Self-acting Slotting Machines.—Two machines of different sizes were exhibited, having respectively 18 inches and 6 inches stroke. They have independent upright framing, cast in one piece with the sole or base. The vertical slide for the cutter-holder or ram is continuous, or in one piece, instead of in two separate shorter slides; thus a continuous bearing is given, which stiffens and steadies the ram, and increases the duration of the wearing surfaces. The feed is taken from a horizontal cam on the spindle, downwards through an upright shaft, which moves a horizontal shaft, from which the feeds for the longitudinal, transverse, and circular motions of the table, are transmitted by spur-wheels and screws for the first and second motions, and by a worm

and worm-wheel for the third motion. The worm is in two lengths, adjustable, to take up the slack as the thread wears (fig. 78).



SELF-ACTING SLOTTING MACHINE, by Messrs. J. Whitworth & Co.

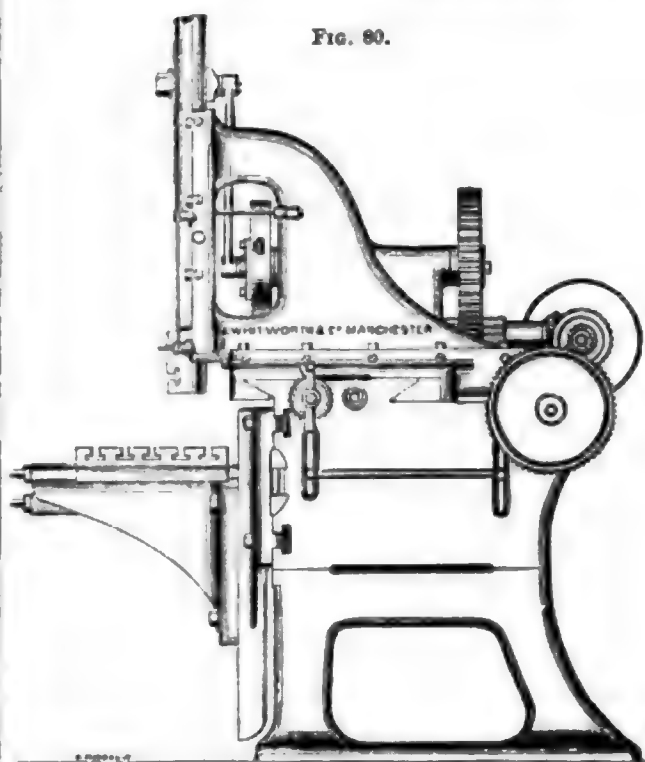
The smaller machine is fitted with additional longitudinal and transverse slides, superposed upon the self-acting slides, and adjustable by hand, to facilitate the setting, and, in many cases, the shaping of an object (fig. 79).



SELF-ACTING SLOTTING MACHINE (small size), by Messrs. Joseph Whitworth & Co.

The ram, or cutter-holder, is moved by a simple crank-motion, which may be varied by shifting the pin radially in a slot across the face of a disc on the spindle.

8. Self-acting Compound Slotting Machine.—This machine is made with one or more slotting headstocks, mounted on a slide-bed similar to that of the universal shaping machine. The work is fixed on the tables, which are adjustable



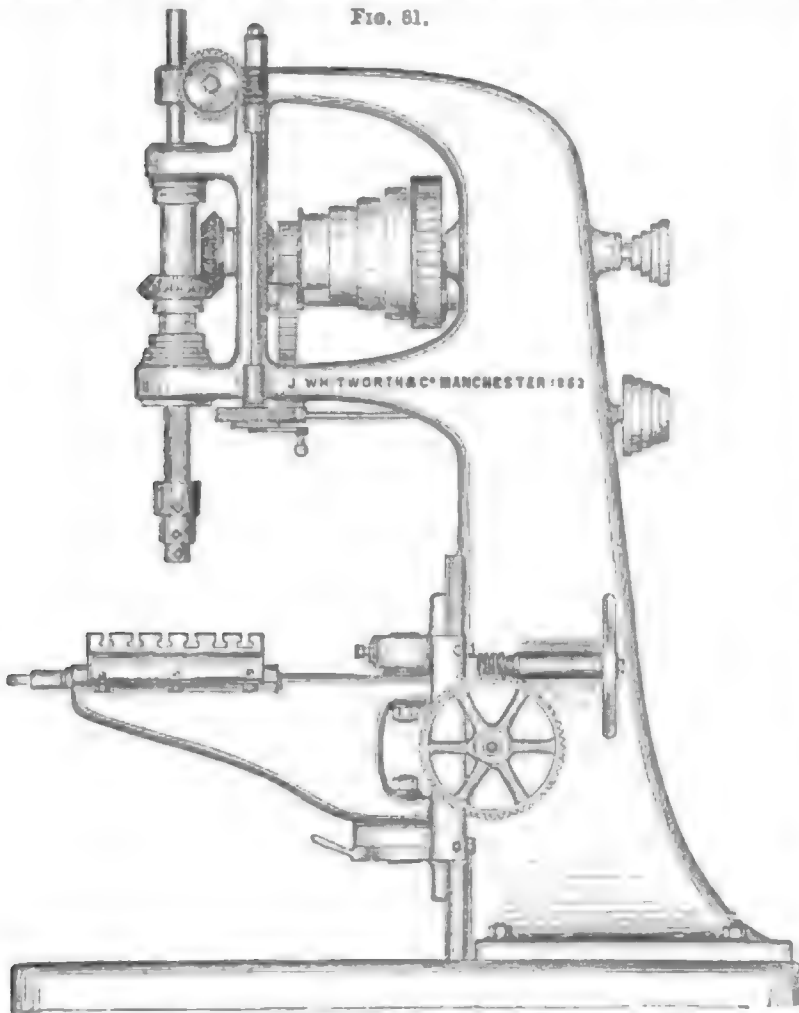
SELF-ACTING COMPOUND SLOTTING MACHINE, by Messrs. Joseph Whitworth & Co.

longitudinally and vertically; and the slotting heads and cutters are made to slide along the bed, each tool having independent self-acting motions for plain and circular work (fig. 80).

9. Self-acting Vertical Drilling and Boring Machines.—Several sizes of this machine were exhibited. They are made with hollow frames; the foundation-plate is planed and grooved, for levelling and fixing work when too high for the table. The table has a vertical slide adjustment, worked by a worm and wheel, and a rack-and-pinion motion; it swivels horizontally on bearings fixed to the vertical slide; and it is adjustable horizontally by means of a radial screw. The drill-spindle, in one machine, slides vertically through a tube, with which it is connected, and driven by a slot and feather; the tube being driven by mitre-wheels from the driving shaft, and working in adjustable conical bearings. In another machine the spindle works in ordinary cylindrical cap-bearings. The back gear, instead of being placed within the frame above the cone-spindle, as formerly, is placed at one side (fig. 81).

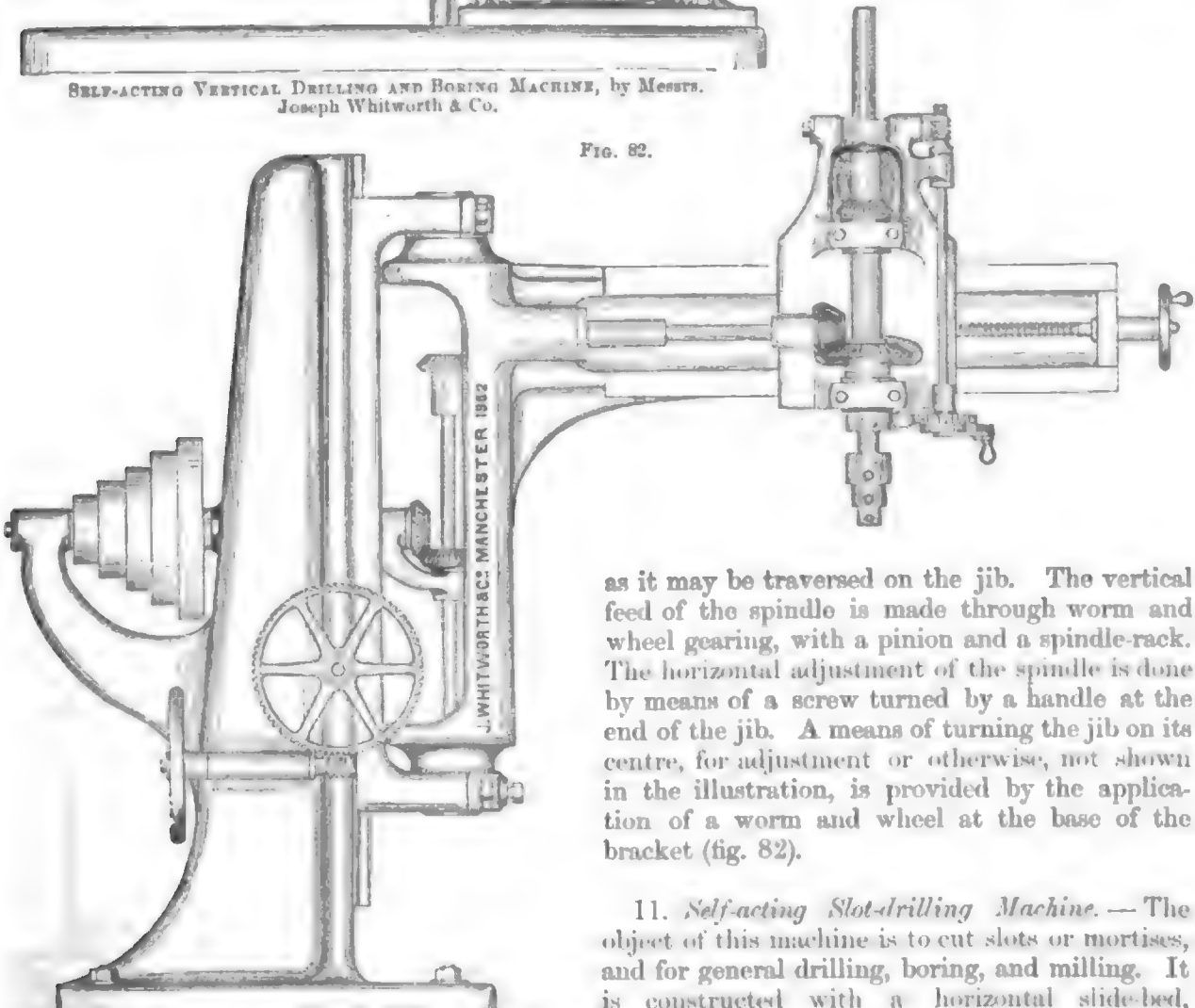
A vertical drilling machine, of very small dimensions, is exhibited, in which the spindle is constructed like a lathe-spindle, with conical steel bearings, and the table, which has compound slides, is moved vertically by the foot. A stop is provided, to give the limit to which the table can be raised, and it acts as a guide in cut-

FIG. 81.



SELF-ACTING VERTICAL DRILLING AND BORING MACHINE, by Messrs. Joseph Whitworth & Co.

FIG. 82.



SELF-ACTING RADIAL DRILLING MACHINE, by Messrs. Joseph Whitworth & Co.

ting mortises or slots, or in milling or shaping light work. This machine is designed and used for the manufacture of rifles, philosophical instruments, and other light work.

10. *Self-acting Radial Drilling Machine.*—This machine is made with a vertical hollow frame. The radial arm, or jib, carrying the drill-spindle, is movable through an arc of 200° , and will compass any object within that range. It is hung, and it swivels upon, a bracket which slides vertically upon the flat face of the frame, to various elevations, as may be required. It is raised by means of a worm and hand-wheel. The motion to turn the drill-spindle is derived from the cone pulley, through mitre-gear, behind the sliding bracket, and a telescopic shaft, which is capable of drawing out or contracting, in connection with the spindle-headstock, accordingly

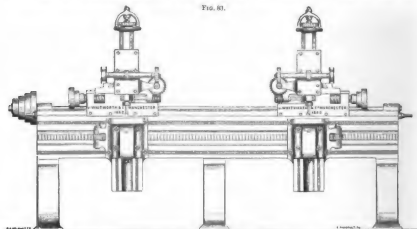
as it may be traversed on the jib. The vertical feed of the spindle is made through worm and wheel gearing, with a pinion and a spindle-rack. The horizontal adjustment of the spindle is done by means of a screw turned by a handle at the end of the jib. A means of turning the jib on its centre, for adjustment or otherwise, not shown in the illustration, is provided by the application of a worm and wheel at the base of the bracket (fig. 82).

11. *Self-acting Slot-drilling Machine.*—The object of this machine is to cut slots or mortises, and for general drilling, boring, and milling. It is constructed with a horizontal slide-bed, grooved in front to receive the several tables

used for holding the work, which are movable vertically and longitudinally. The drill-spindle revolves in conical case-hardened steel bearings within a tube, which is made octagonal in section exteriorly, and is adjustable in its bearings, like the spindle of a turning-lathe, by means of a "tail-pin" and lock-nuts on the upper end, to

prevent play of any kind. The means for imparting the rotary motion of the drill, the vertical feed, and the reciprocating traversing movement of the drill to form the slot, are all contained within, and carried upon and with the headstock; the base of the headstock being movable longitudinally by a screw in the bed

FIG. 83.

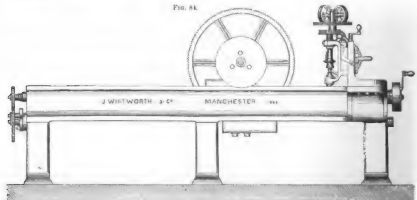


SELF-ACTING SLOT-DRILLING MACHINE, by Messrs. Joseph Whitworth & Co.

of the machine, for preliminary adjustment. The drill-spindle is, further, adjustable transversely, on a cross slide. Thus the spindle is controlled by three slides for different purposes. The vertical feed is imparted to the octagonal tube by means of a rack on its face; the tube descends with and materially stiffens the spindle against the lateral strain peculiar to slot-drilling. The horizontal feed, or reciprocation,

is communicated by a worm and wheel on a horizontal slotted disc, forming a crank-motion, like that of an ordinary slotting machine, in which, by shifting the stud, the travel, or length of the slot to be drilled, may be fixed. The horizontal feed varies, in virtue of the crank motion, from nothing at the commencement and end of the travel, to a maximum at the middle of it (fig. 83).

FIG. 84.



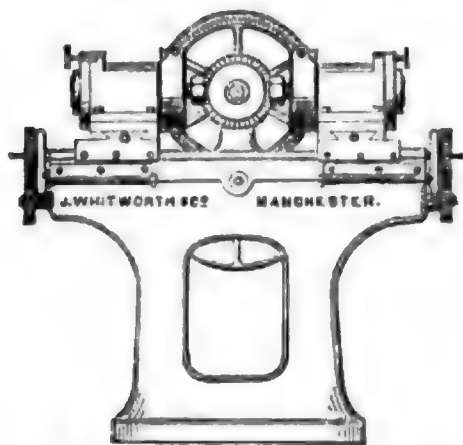
SELF-ACTING WHEEL-CUTTING MACHINE, by Messrs. Joseph Whitworth & Co.

In another kind of slot-drilling machine, for cutting slots which do not run parallel to the length of the object—as, for example in the cross-head of a steam-engine—the main frame carrying the drill-spindle is stationary, and the work is traversed under the drill.

12. Self-acting Wheel-cutting Machine.—This machine is designed for cutting the teeth of spur, bevil, and worm-wheels, in metal or wood. It will cut wheels up to ten feet in diameter, and pinions of the smallest diameter required in engineers' work. The cutter is circular, and is fixed on a vertical spindle revolving in a frame, adjustable vertically, and traversed by self-acting means horizontally across the rim of the wheel to be cut. The wheel is fixed on a horizontal axis on a frame adjustable longitudinally on the bed, according to the diameter of the wheel. The dividing of the wheel—that is, the changes of position for cutting successive teeth, is accomplished by means of change-wheels and worm-wheels (fig. 84).

13. Self-acting Nut-shaping Machine.—This machine is applicable for shaping and squaring nuts, bolt-heads, ends of shafts, &c., with two circular cutters, shaping two opposite sides at once; and two concentric chucks for holding two objects, to be operated upon at the same time.

FIG. 85.



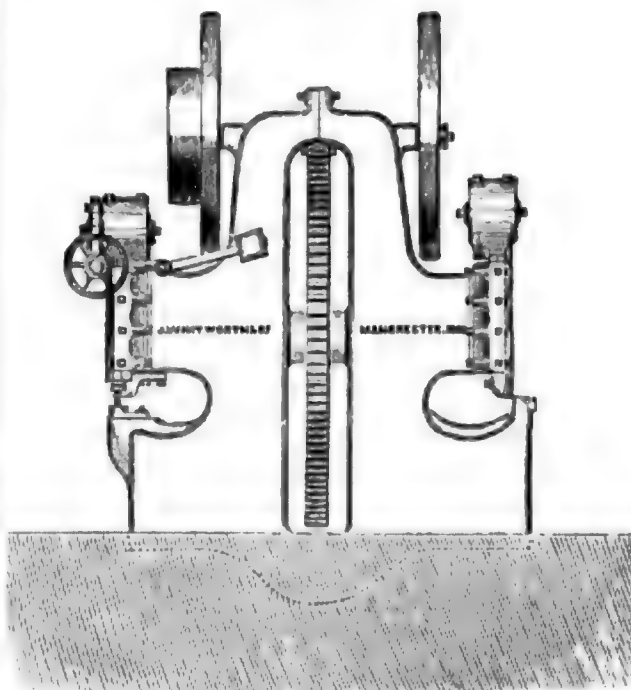
SELF-ACTING NUT-SHAPING MACHINE, by Messrs. Joseph Whitworth & Co.

There are duplicate compound slide-rests, with separate self-acting and disengaging motions, to prevent injury from the cutters. The concentric chucks are placed on opposite sides of the circular cutters, with the view of balancing the cutting strains and doubling the quantity of work that can be done with only one chuck (fig. 85).

14. Punching and Shearing Machine.—This machine is made with a hollow frame, with a double fly-wheel, and driven by means of a single pinion and a large wheel, with eccentric motions for working the punching and shearing slides, through the medium of connecting-rods. The

eccentric or main shaft is of steel-iron; the punch is balanced by a weighted lever, and it may be raised, or put out of action, by means

FIG. 86.

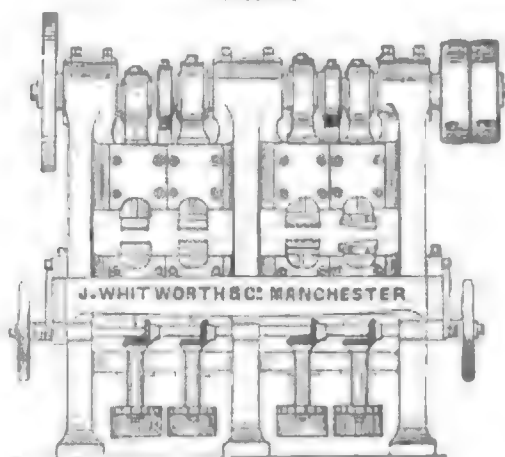


PUNCHING AND SHEARING MACHINE, by Messrs. Joseph Whitworth & Co.

of a hand-wheel and worm, without stopping the machine (fig. 86).

15. Ryder's Forging Machine.—This machine is adapted for forging small objects in quantities, where the cost of the swages—generally of cast-iron—forms a comparatively small item. This machine admits a forging six inches square. The upper swages, four in number, work in hexagonal

FIG. 87.



RYDER'S FORGING MACHINE, by Messrs. Joseph Whitworth & Co.

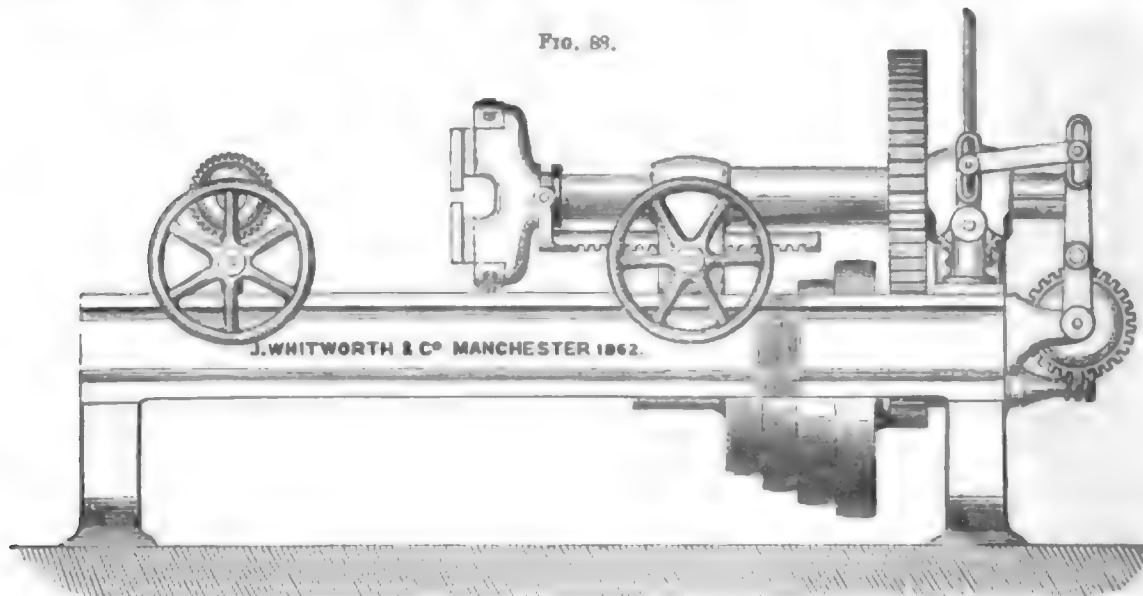
slides, which are adjustable, and are raised and depressed by eccentrics formed out of the solid driving shaft of steel. The lower swages are raised by means of screws and hand-wheels to the required height, and one or more of them may be raised during the swaging of a piece, so as to produce taper work (fig. 87).

16. *Sawing Machine for Hot Iron.*—This is a useful machine in connection with Ryder's forging machine. It is arranged with a slide bed, on which the slide carrying the circular saw is movable longitudinally. The iron to be sawn is placed in an angular grooved bed, and the saw is drawn through it by means of a screw and nut.

17. *Bolt and Nut Screwing Machine.*—This machine is constructed with a hollow mandril, with universal chuck for holding the bolt or

other article to be screwed. There are four radial screwing dies, two on each side of the centre. They are cut by master taps, of a diameter larger than that of the bolts to be screwed, by twice the depth of the thread, in order that the diameter of the tops of the threads in the dies may be equal to that of the tops of the threads on the screwed bolt; so that, these particular diameters being equal, the obliquity of the thread to be started on the circumference of the blank bolt, and ultimately cut upon it, will be correct for the top of that thread, and will

FIG. 89.

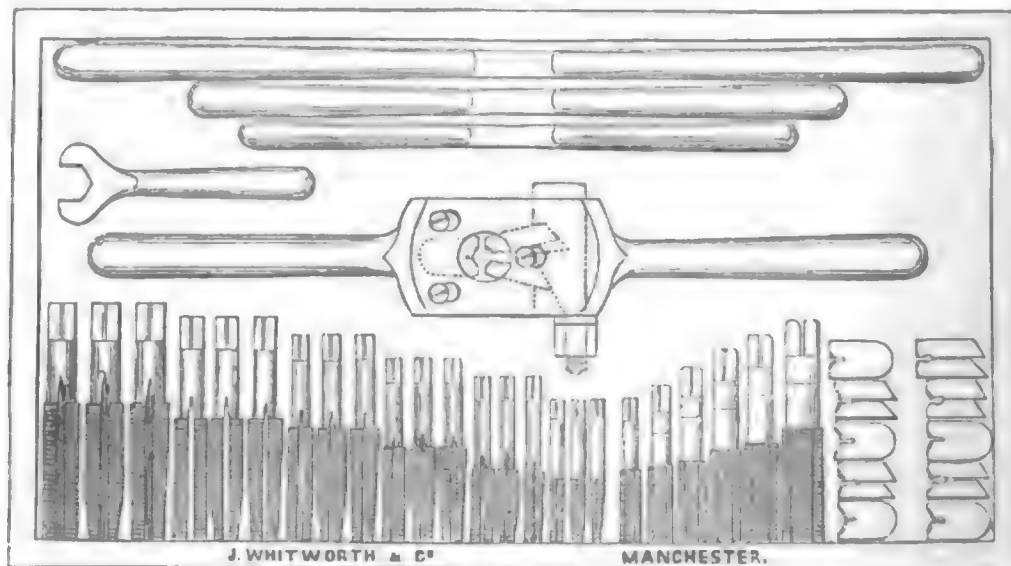


BOLT AND NUT SCREWING MACHINE, by Messrs. Joseph Whitworth & Co.

thus start the thread at the proper pitch. The cutting edges of the dies are filed off to an acute angle, so as to cut with ease, like a chasing "tool" or cutter (fig. 88).

The dies having been, in the first place, closed upon the bolt, it is passed through them, and the thread traced upon it. It is again passed and repassed through the dies, which are drawn

FIG. 80.



HAND-SCREWING APPARATUS, by Messrs. Joseph Whitworth & Co.

closer and closer, until the full thread is formed.

The taps for screwing nuts are tapered at the points, and fluted longitudinally, to form cutting edges. The reduced threads, entering the nut, cut their way through in succession, and the

screw is completed by the full threads on the body of the tap.

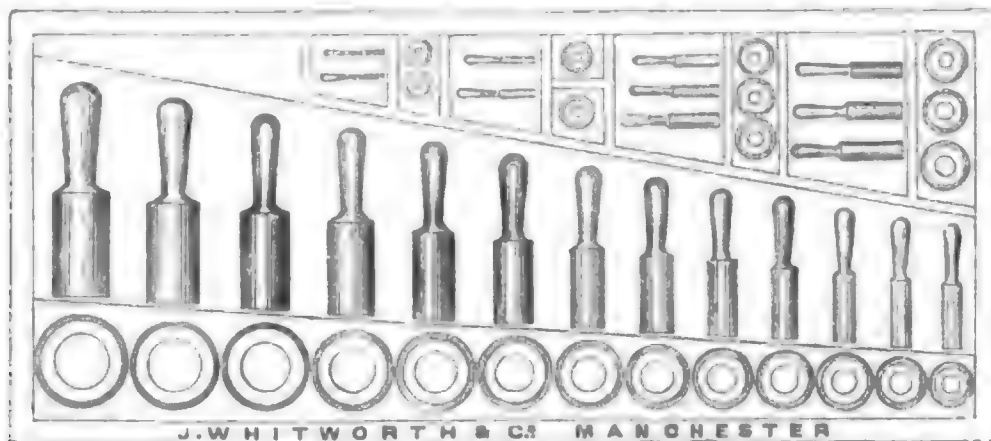
18. *Hand-screwing Apparatus.*—This comprises screw-stocks, dies, taps, and wrenches.

The screw-threads are, in section, formed alike in angle and shape, on the uniform system introduced by Messrs. Joseph Whitworth & Co. The screw-stocks are fitted with three dies, of which one is stationary, and acts as a "dummy," to support and guide the bolt, without cutting it; the two others are the cutting

dies, set up to the work by a double-inclined wedge or key (fig. 89).

19. *Internal and External Cylindrical Gauges.*—These gauges are standards of size, made exact to the national measure, and tested by the measuring machine (fig. 90).

FIG. 90.



INTERNAL AND EXTERNAL CYLINDRICAL GAUGES, by Messrs. Joseph Whitworth & Co.

CHAPTER III.

ENGINEERS' TOOLS EXHIBITED BY MESSRS. SHARP, STEWART, AND CO., MANCHESTER.

Messrs. Sharp, Stewart, & Co. exhibited a series of tools nicely and elegantly designed, carefully and thoroughly detailed, and well constructed. The collection comprised several original machines—matured within the last few years—remarkable for the rapidity and accuracy of their performance.

1. *Double Face-plate Lathe.*—This lathe has two face-plates, 6 feet 6 inches in diameter, for turning and boring wheels and tyres up to 6 feet in diameter, either separately or on their axles, and it bores the tyres or the naves of the wheels by self-acting movements. The bed is made unusually strong, and is designed to be independent of the expensive and massive foundation required for some lathes of this size. The headstocks are heavy "box" or hollow castings, with adjustable gun-metal bearings of large surface for the spindles, which are supplied with lock-nuts to prevent end play. The face-plates are driven each by an exterior spur-wheel or circular rack cast on the back of the face-plate, of the greatest available diameter, nearly equal to that of the face-plate. The nave of the face-plate is recessed, and has a bearing upon the circumference of the collar on the spindle, to which it is bolted, which adds materially to the stiffness of the connection, more particularly as the bearing on the collar is in line with the driving circular rack on the back of the face-plate, and therefore also with the driving strain. The lathe is driven from two cone pulleys, —a four-speeded cone with a pinion to drive a spur-wheel on the main spindle, being single gear

for quick speeds, suitable for boring and turning the naves of wheels. Secondly, a three-speeded cone with a pinion to drive a spur-wheel on the through shaft in the bed, from which a couple of spur-pinions gear with and turn the face-plates: this comprises a double reduction of speed, for low speeds for turning the larger diameters. The face-plates are formed with a few long slots instead of the numerous ordinary square holes, for convenience in applying holding-bolts to the work. The face-plates are provided with four-jaw "screw chucks" for fixing tyres and wheels to be bored. Two or four "tool-rests" are provided, as may be required, for duplex turning or boring; all of them with self-acting motions. Each pair of rests is placed upon a transverse slide or base-plate, bolted to the bed by crosshead bolts and nuts adjustable in longitudinal grooves in the bed; the rests are fixed to the transverse base-plate by dovetail-headed bolts and nuts in a pair of grooves formed in the base-plate. By this means the rests may be adjusted in position with great facility. The feed for the cutters is obtained from the respective cone-spindles by means of overhead connections. The headstocks are adjustable apart by means of rack and pinion, and the bed is sufficient in length to admit wheels and axles of the widest gauge. A self-acting feed for the boring bar is derived from the end of the back headstock with overhead connections.

2. *Self-acting Shaping Machines.*—Two machines were exhibited, capable of planing or shaping flat, circular, or angular work, with maximum strokes respectively of 25 inches and 6 inches. In the 25-inch machine two tables are applied for supporting long objects at two places. The ram is driven by a slotted link, vibrating on one end, with quick return, and the connection

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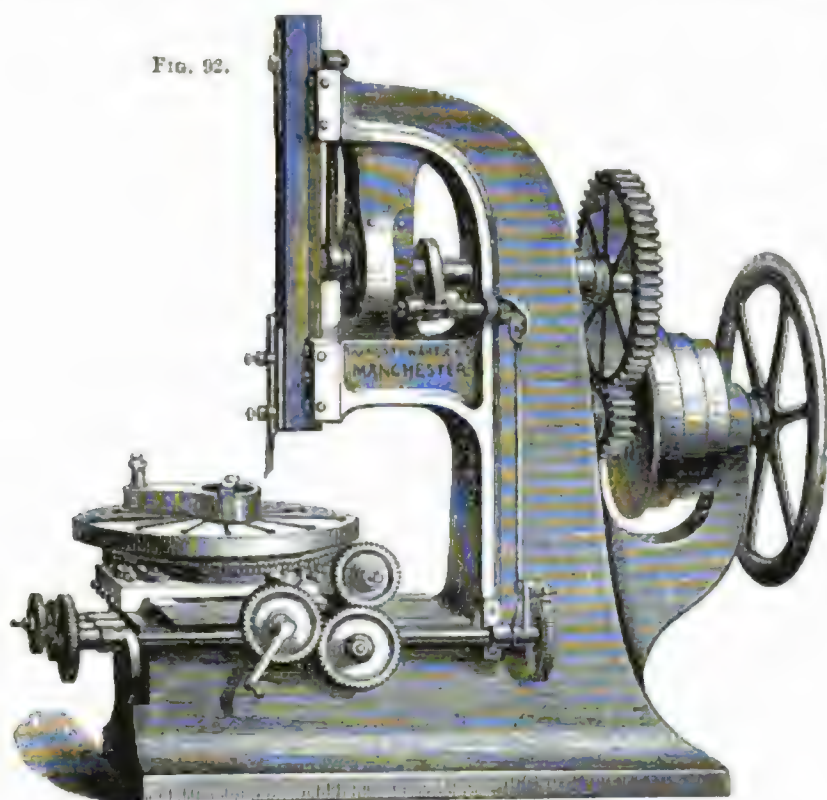
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culty forged approximately for completion by hand-labour without consuming much time, and involving the frequent reheating, and consequent deterioration, of the metal (fig. 92).

so as to allow of larger objects being placed on the sole-plate of the machine. The machine is compact and self-contained (fig. 93, page 142).

The smaller drilling machine has a $2\frac{1}{2}$ -inch spindle; it drills or bores a 2-inch hole to a depth of 7 inches, and receives an object 34 inches in diameter. In general design it is similar to the larger machine; but it has only single driving-gear, with a four-speed cone, and the table is raised or lowered by means of a screw and handle.

FIG. 92.



SELF-ACTING SLOTTING MACHINE, by Messrs. Sharp, Stewart, & Co.

4. *Vertical Drilling Machines.*—Two machines of this class were exhibited. The larger machine has a $2\frac{1}{2}$ -inch spindle, and is adapted for drilling or boring a 4-inch hole 12 inches deep; it admits an object 42 inches in diameter. The driving cone-pulley is double-gear, and the whole of the gearing is placed within the frame. The vertical feed for the drill-spindle is communicated through a screw, which is a separate continuation upwards of the drill-spindle, and connected with it like the ordinary rack-feed, so that the spindle may revolve while the screw is retained stationary by the aid of a feather working in a slot. A nut on the screw being turned by gearing, the drill descends without any of the irregularity or play incidental to the rack-feed. The motion for the feed is derived from the cone-spindle at the back of the frame, with a pair of small cone-pulleys turning a worm which works an upright shaft near the drill-spindle, from which the nut is turned by means of spur-wheels. The spindle turns in adjustable conical bearings, by means of which, play or looseness of the spindle in its bearings may be taken up. The table is grooved on the top for fixing objects, and is capable of sliding vertically on the frame for convenience in placing objects upon it by self-acting means; a motion for this purpose being derived from the feed-worm shaft by bevil gearing, to turn a vertical screw placed in front of the frame, working through a nut let into the table. The table is arranged to swivel horizontally,

enters the column and turns, by a pair of mitre wheels, an upright shaft passing through the top of the column; from this shaft, the power is brought down the face of the jib-slide by an exterior shaft driven by spur-gear at the top of the column, and is taken off horizontally by means of mitres by a shaft extending behind the drill-frame to the end of the jib. To facilitate this arrangement, the jib is made of a box or hollow form, uniting strength and stiffness with space for the horizontal shaft. But the power is to be transmitted from this shaft to the drill-spindle, which is done through a short intermediate shaft carried by the drill-frame, by means of a pair of spurs and a pair of mitres. On this plan, the necessity for a telescopic shaft is avoided, and the power is brought to the front by the pair of spurs and the intermediate shaft. From the intermediate, a motion is derived for the vertical feed of the spindle, 8 inches in extent, by means of small three-speeded cones, worm, spur-gear, and screw, similar to the screw-feed employed in the vertical drilling machine. The spindle works in adjustable conical bearings. The horizontal traverse of the spindle is derived from a screw fixed in front of the drill-frame, on which a nut is traversed by mitres and a hand-wheel. Thus, both the hand-wheels for the horizontal and the vertical motions of the spindle, are brought conveniently close to the workman, one on each side of the spindle. The jib itself may be raised or lowered by power, by means of a screw on

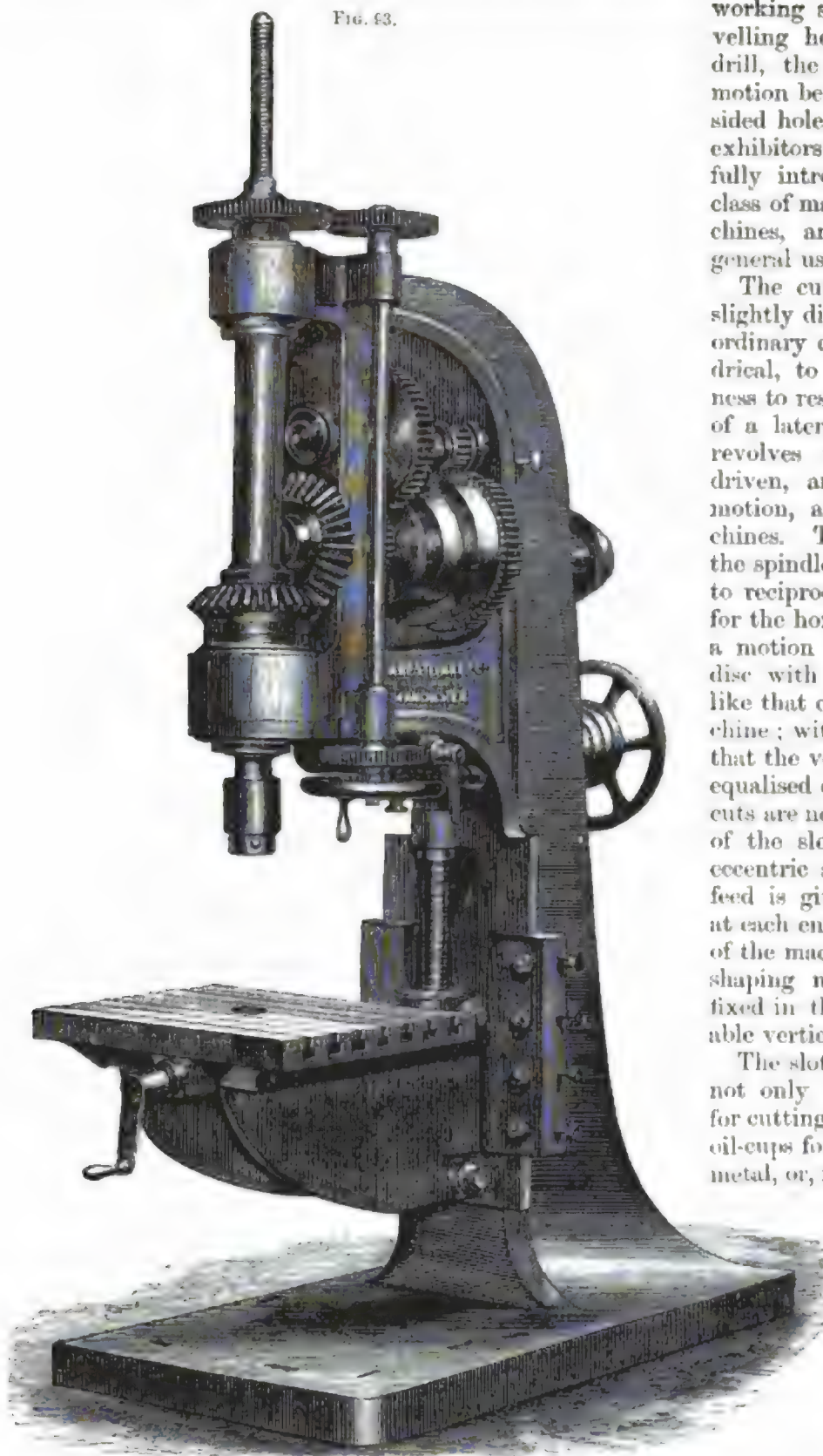


FIG. 93.

VERTICAL DRILLING MACHINE, by Messrs. Sharp, Stewart, & Co.

the lower end of the outer upright shaft, with which it may be engaged and disengaged by means of a hand-lever.

The base-plate is limited in size, and is not extended under the jib; it is intended by the exhibitors to stand on a stone foundation.

6. Slot-drilling Machines.—These machines present the contrivance of a descending drill,

working simultaneously with a travelling headstock which carries the drill, the object of the compound motion being to cut a slot or parallel-sided hole, in a piece of metal. The exhibitors have the merit of successfully introducing and maturing this class of machine-tools as standard machines, and of bringing them into general use.

The cutter or drill is of a form slightly differing from those used for ordinary drilling; the stem is cylindrical, to provide the needful stiffness to resist the severe lateral strain of a lateral cut. It is fixed in and revolves with a spindle, which is driven, and has a descending feed-motion, as in ordinary drilling machines. The headstock which carries the spindle is, at the same time, made to reciprocate or traverse alternately for the horizontal feed, on its bed, by a motion from a horizontal slotted disc with a connecting-rod, derived like that of the ram of a slotting machine; with this important difference, that the velocity of traverse is nearly equalised or rendered uniform, and the cuts are nearly equal from end to end of the slot, by the intervention of eccentric spur-gear. The descending feed is given when the drill arrives at each end of the traverse. The bed of the machine is similar to that of a shaping machine, and the table is fixed in the same way, being adjustable vertically and horizontally.

The slot-drilling machine is useful not only for cutting slots, but also for cutting key-ways, forked ends, and oil-cups for lubricators out of the solid metal, or, finally, for ordinary drilling.

Three different machines were exhibited:—first, the ordinary single-headstock machine, capable of making one slot at a time, 6 inches long, 4 inches deep, and $\frac{3}{4}$ inch wide, in objects of moderate size (fig. 94); second, a single-headstock machine for special large work, capable of making

one slot 13 inches long, $11\frac{1}{2}$ inches deep, and $4\frac{1}{2}$ inches wide (fig. 95, page 144); third, a double-headstock machine—with two independent headstocks—to make two 13-inch slots at once in long objects.

7. Bolt and Nut Screwing Machines.—In these machines, which are on Seller's patent, the bolt to be screwed is stationary, and the cutting dies

revolve,—a motion the reverse of that of ordinary machines. The principal feature in the machine is the conical form of the dies, which are funnel-mouthed or widened at the entrance by cutting away the threads so as to receive the entire bolt and finish the screw at one cut. No reverse or backward motion through the dies is required, the bolt being released by the withdrawal of the dies at the termination of the cut.

There are three dies, movable radially in a box; they make three successive cuts into the bolt, one cut to each, so that, in cutting a screw, the bolt is finished in one pass through the dies by three cuttings made simultaneously,—the second and third cuts successively deeper than the first. The dies being disengaged radially, the bolt is free to be withdrawn without being reversed and unscrewed out of the dies as in other processes, by which they are saved from

bed holds oil and cuttings, and the dies are lubricated by dipping into the oil. At the commencement of the cut the bolt is forced into the dies by the aid of a rack cast on each side of the bed, and a hand-ratchet. The dies, once set, do not require further adjustment until another size of bolt is to be screwed.

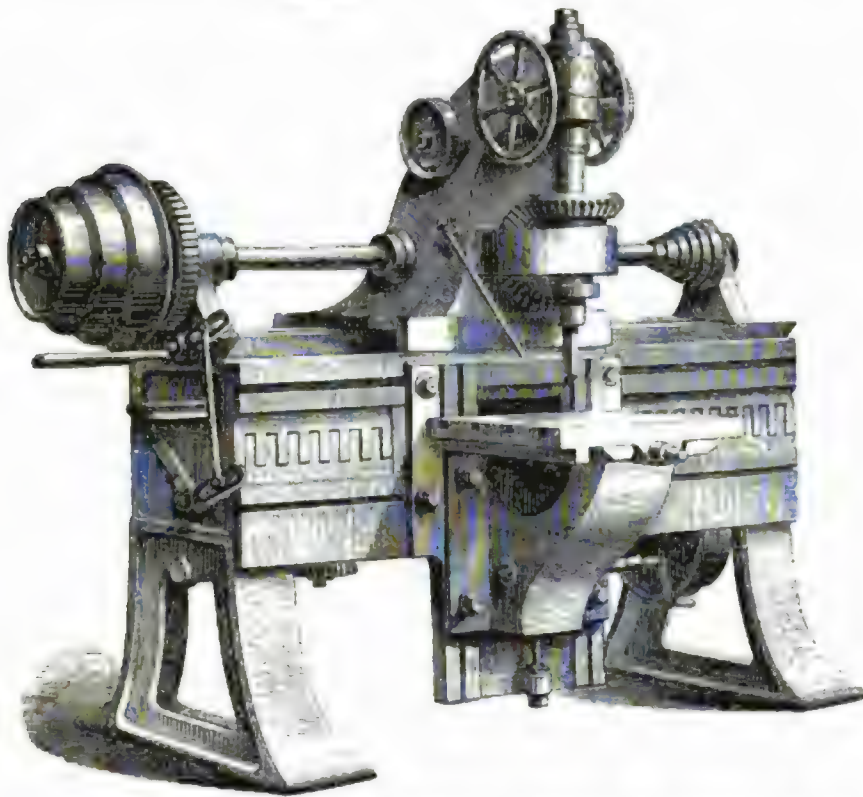
Four sizes of this machine were exhibited, capable of screwing from $\frac{1}{4}$ inch to 3 inches in diameter (fig. 96, page 145).

8. Punching and Shearing Machine.—This machine is designed for punching holes up to $1\frac{1}{4}$ inches diameter in $1\frac{1}{4}$ -inch plates, and for shearing $1\frac{1}{4}$ -inch plates. It is made with compound driving gear to reduce the speed for the main shaft by two stages, and the shearing slide is placed obliquely to admit of bars being cut off at any length. The frame is a hollow or box casting in one piece, in a form of great strength. The first-motion shaft is placed at the top with a fly-wheel, and the intermediate and main shafts are placed directly below it with solid bearings within the frame. The main shaft works the punch at one end and the shears at the other, with alternate movements, by means of eccentrics formed solid on the shaft and working within box-shaped slides, in each of which the eccentric-strap bears upon the upper side to lift it, and upon a block of steel resting on the bottom of the slide, to push it down. By the temporary removal of this block of steel, for which a simple hand-lever is provided, the punch may be disengaged instantly. The die of the lower knife of the shears and that of the rest beneath the punch are held by projections of the frame, and the whole apparatus is self-contained, and

works independently of foundations. The base of the frame is confined at the extremities for the convenience of the attendant in placing his feet, and is sufficiently spread in the middle to afford a steady lateral support for the frame. The oblique position of the shears is a feature worthy of notice, for the convenience of admitting long lengths of bars or narrow plates to be placed and cut off in the machine. The punch and the shears are each placed at 18 inches clear of the frame horizontally (fig. 97, page 145).

9. Painting Machine.—This machine is designed for painting the edges and surfaces of planks, whether plain or moulded. A reservoir of paint is placed at the upper part, containing

FIG. 94.

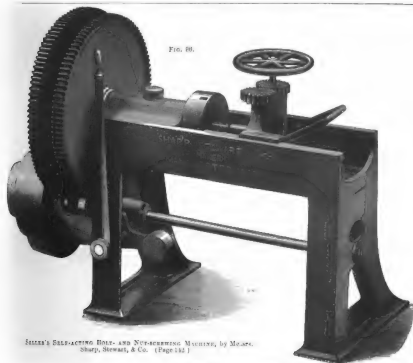


SLOT-DRILLING AND GROOVING MACHINE, by Messrs. Sharp, Stewart, & Co.

back wear. The dies are held in place for screwing, by cams on a cam-plate revolving at the same speed as the die-box, and they are released by causing the cam-plate to over-run the die-box, which is done by engaging the spur-wheel which carries the cam-plate with a pinion on the first motion shaft, put in gear by a friction-cone and hand-lever. By means of this differential motion, the cams act upon and withdraw the dies from the bolt. The head of the bolt is held between two blocks forming a vice, with segmental openings, which are mutually brought together by two screwed bolts, one tapped into each, turned in unison by a hand-wheel and a pair of small spurs. The die-stock or box slides with a long bearing on a cast-iron trough-bed, planed. The

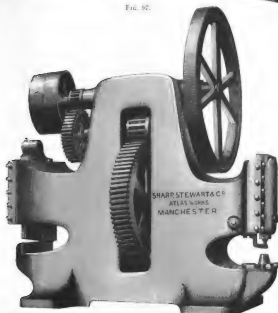


FIG. 86.



ELLIS'S SELF-ACTING BOLT- AND NUT-SCREWING MACHINE, by Messrs.
Sharp, Stewart, & Co. (Page 142)

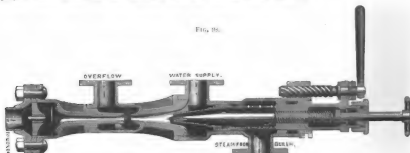
FIG. 97.



PUNCHING AND SHEARING MACHINE, by Messrs. Sharp, Stewart, & Co. (Page 145)

is not found materially to interfere with its action. The damage done to feed-pipes, particularly in frosty weather, by pumps, disappears with the application of the injector. It is serviceable under a great variety of circumstances, and is subject to very little wear and tear. It will work at any pressure of steam, and being independent of engine power, is useful for filling the boiler when the engine is standing, or in connection with boilers when no engine is employed near them; as, for example, at the

International Exhibition, where the injector supplied with perfect regularity the feedwater for the steam boilers which supplied the steam for the machinery in motion in the Western Annex during the whole period of six months. Many other illustrations of the application of the injector were exhibited. Injectors are made of from two to twenty-six millimètres, or from the twelfth of an inch to one inch diameter of the nozzle, into which the feed-stream enters (fig. 98).



GIFFARD'S WATER-INJECTOR, by Messrs. Sharp, Stewart, & Co.

CHAPTER IV.

MACHINE-TOOLS EXHIBITED BY MESSRS. BEYER, PEACOCK, AND CO., MANCHESTER.

Messrs. Beyer, Peacock, & Co., exhibited two large tools—a wheel-lathe and a frame-drilling machine—which give evidence of the same clear perception of the requirements in the construction of a machine, and the mastery detail and workmanship, which are manifested in the locomotive engine exhibited by them.

1. *Double Face-plate Lathe*.—The bed of this lathe is 16 inches deep, and very strongly proportioned. It is placed upon four transverse cast-iron beams or girders, which rest on the foundation. The face-plates are 7 feet 6 inches in diameter, for turning and boring wheels and tires up to 7 feet in diameter. The lathe is similar to a lathe constructed by Mr. Beyer, and exhibited in 1851, with some improvements in addition. The novel features of the lathe exhibited in 1851, consisted in placing the driving pinion-shaft below the surface of the base-plate; the introduction of a cone-pulley on a back shaft, with single gearing to the fast headstock, and the self-action of the compound slide and boring rests by means of chains or bands worked from the head-gear. The lathe exhibited in 1862, contains, in addition to these improvements, a third cone-pulley on a back shaft for the following or shifting headstock, and an improved boring bar and rest.

By the application of independent four-speed cones to the headstocks, one or both face-plates

may be engaged for boring or turning separately. The third cone, also of four speeds, is hung on a back shaft with bearings on one of the headstocks, to turn by means of a pinion and wheel the driving shaft below, with sliding pinions for the slow motion of the face-plates. The face-plate spur-wheels are cast solid on the backs of the face-plates, with exterior teeth. The bearings of the lathe-spindle are made in two pieces, the lower halves being turned, and the head-stocks bored to receive them; the upper halves are square. The cutter-rests, or tool-rests, are distinguished for their widely-set sliding surfaces. The boring bar works in a split brass bush in the nose of the lathe-spindle; and is guided by the boring-rest, which is a cast-iron stand on the baseplate, in which it has a bearing, and is prevented from turning round by a key sliding in a groove in the bar. The feed of the boring-bar is given from a screw working in a nut on the stand; a ratchet-wheel is fixed on the screw, and is turned by means of a click, worked by an overhead motion, by which motion the screw is advanced and pushes forward the boring-bar. The screw-nut is bedded into a carrier fixed to the stand with slot-holes, so that it may be lowered, and the screw and nut set free to allow of the boring-bar being taken out endways.

2. *Frame-drilling Machine*.—This machine is specially adapted for locomotive work, as frame-plates and tube-plates, and is illustrated by Plate XVIII. It has a long bed, 25 feet in length, and 5 feet 4½ inches broad, which is planed from end to end, and carries three or more boring

DOT

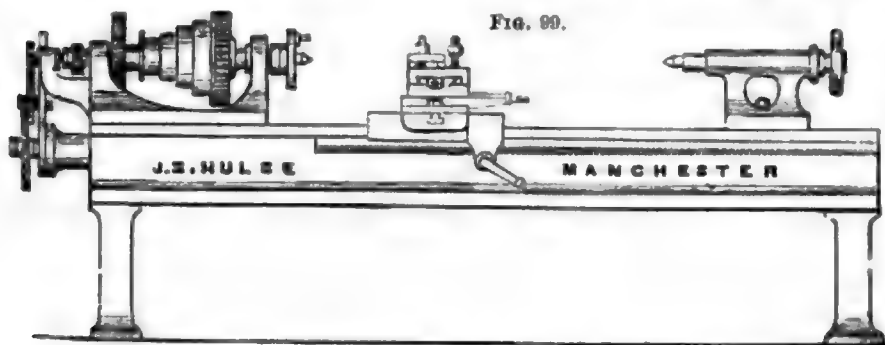
heads, placed across the bed, with bearings on the edges, and movable longitudinally. Each of the three heads shown in the illustration carries a vertical drilling spindle on a carriage with a transverse sliding motion on the head. Thus, the whole surface of the bed is commanded by the longitudinal and transverse motions, and an object, 25 feet long and 5 feet wide, may be drilled at any point. The three drills are driven by a common driving shaft running alongside the bed; from which the motion is taken by mitres and a pair of three-speed cones to each head, of which the upper cone is fixed on the end of a transverse shaft within the cross-head, from which the drill-spindle is driven by gearing. The vertical feed is self-acting, and may be worked by hand. The lower cone-pulleys are framed so as to swivel upon the longitudinal shaft, for which a handle is provided; and the belt may be slackened and thrown off either of them, and the drill stopped, by throwing up the cone.

The application of this three-headed drilling machine to the drilling of the side frame-plates of locomotives is obvious; one head may be devoted to each axle-guard. But it is equally applicable for accurately drilling holes in any other piece of work in straight lines, and in lines at right angles to each other. It also saves labour in drilling large objects by bringing the drill to its work, instead of moving the work to the drill; and it saves time also in bringing as many drills to bear upon the object as may be required. (Plate XVIII.)

CHAPTER V.

MACHINE-TOOLS EXHIBITED BY MR. J. S. HULSE, MANCHESTER.

Mr. Hulse exhibited a selection of tools of excellent workmanship, chiefly of small dimensions.

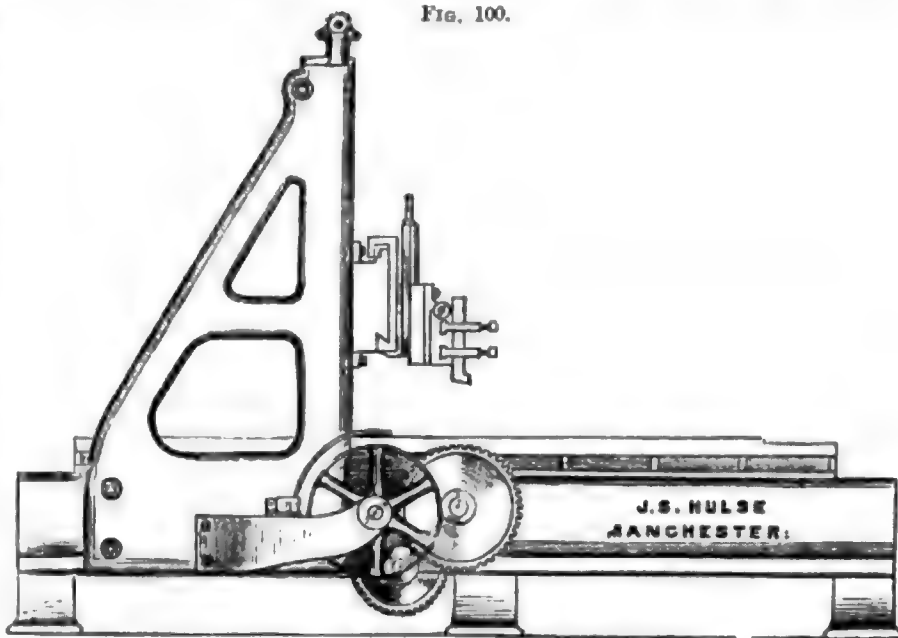


SCREW-CUTTING AND SLIDING LATHE, by Mr. J. S. Hulse, Manchester.

1. *Screw-cutting and Sliding Lathe*.—This is an 8½-inch lathe, with a guide-screw for sliding and screw-cutting, and a rack for quick traverse by hand. It has a four-speed cone, with conical bearings, lock-nuts, and a tail-pin. The back shaft slides longitudinally out of gear. The tail-pin is permanently set in a bracket cast on the end of the headstock, and the motion for the change-wheels is taken off the end of the cone-spindle by carrier-spurs, of equal diameter, on a short intermediate shaft, supported by the tail-pin bracket (fig. 99).

2. *"Single-speed" Lathe*.—This lathe has a

FIG. 100.



PLANING MACHINE, by Mr. J. S. Hulse.

6½-inch centre, with a five-speed cone and a tail-pin. It has not back gear.

3. *Planing Machine*.—This machine planes 7 feet long, by 2½ feet wide, and the same height. The table is driven by a rack-and-pinion motion from side spur-gearing. The self-acting traversing and horizontal feed-motions are simply arranged. A pair of ratchets are hinged on a pivot, carried by a rocking bracket on the traversing screw-shaft as a fulcrum, to which the feed-motion from the table is communicated; one or other of the ratchets being engaged with spurs on the traversing screw, or the transverse shaft for the vertical feed. The upright shaft, which brings up the feed from the table, is continued to the top and gears with the horizontal shaft, which works into the vertical screws that control the transverse slide (fig. 100).

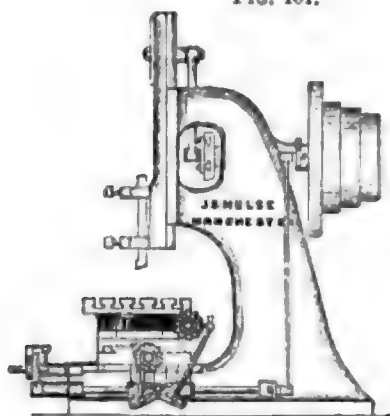
A moving cutter-frame is exhibited, which may be fixed to the table, to move with it, for planing a stationary object fixed to the side of the bed.

4. *Shaping Machine*.—This is a small tool, with $3\frac{1}{2}$ -inch stroke. The driving-pulley is made heavy to act as a fly-wheel.

5. *Bench Slotting Machine*.—This tool has a 4-inch stroke; it has a three-speed cone, over-

cones at the back of the frame, with worm and spur gear. The spindle works in cylindrical bearings with caps. The table is elevated by means of a rack and pinion, and worm gear; it has also two traversing slides (fig. 102).

FIG. 101.

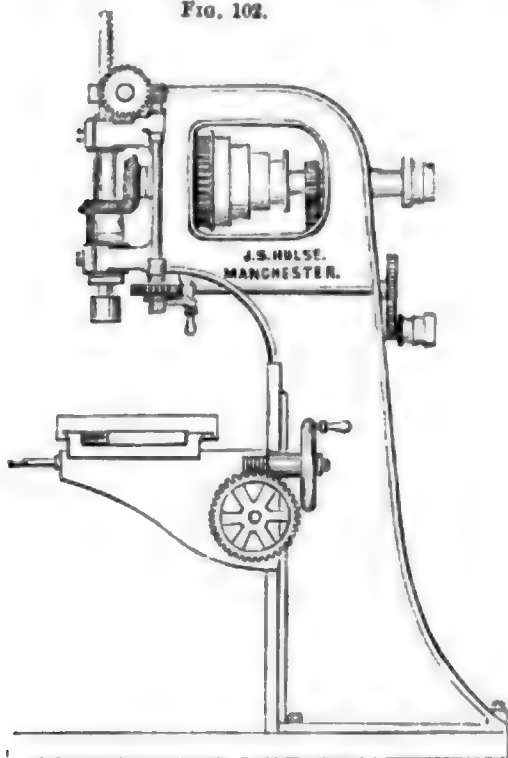


BENCH SLOTTING MACHINE, by Mr. J. S. Hulse.

hung on the spindle, without back gear; the ram works in one long slide. The disc is overhung. The feed is taken from a vertical cam on the disc-shaft, with a spring to keep the feed-lever in contact with the cam (fig. 101).

6. *Vertical Drilling Machine*.—This drill has a $1\frac{1}{2}$ -inch spindle, with a four-speed cone and back gear,—the back shaft being placed in bearings at one

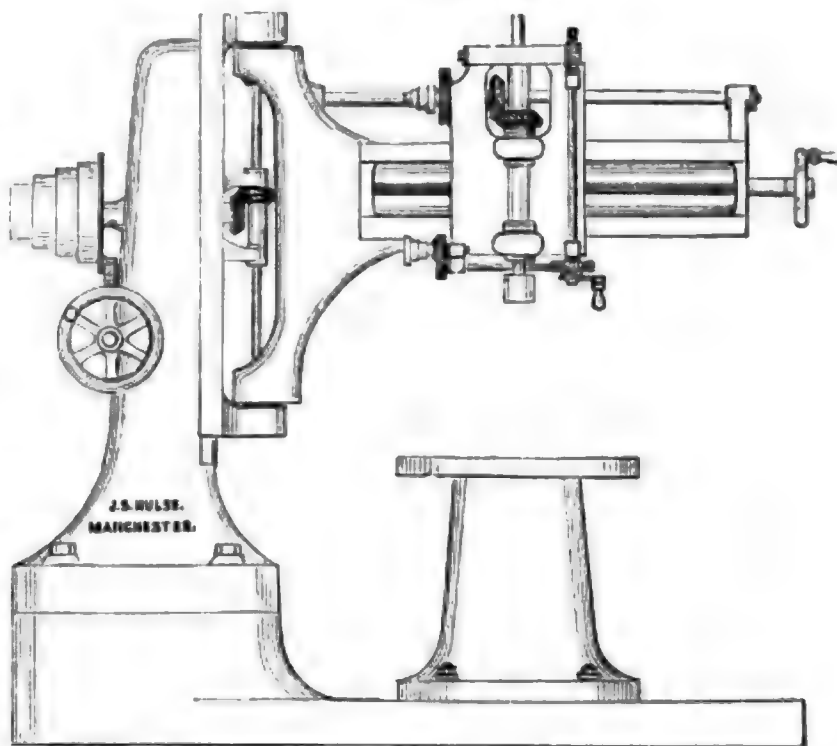
FIG. 102.



VERTICAL DRILLING MACHINE, by Mr. J. S. Hulse.

side of the frame. A rack-spindle feed is applied, and is worked from a pair of small

FIG. 103.

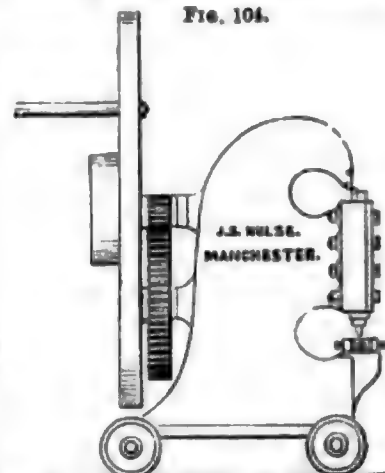


RADIAL DRILLING AND BORING MACHINE, by Mr. J. S. Hulse.

7. *Radial Drilling and Boring Machine*.—The sole-plate of this machine, which has a jib of only 4 feet 6 inches radius, is cast with a raised circular platform at one end, to which the standard is bolted. The jib is hung on pivots in a bracket, which slides on the face of the standard, and the drill-spindle is driven from a four-speed cone, overhung behind the frame,—the power being taken by spur and mitre gearing off a horizontal shaft, situated above the jib, and passing behind the drill carriage. The feed is self-acting, with a hand-wheel, and rack-spindle motion. The jib is elevated by hand, with a spur and worm-wheel motion (fig. 103).

8. *Punching and Shearing Machine*.—This is a small portable machine, on wheels, to punch $\frac{1}{2}$ -inch holes in $\frac{1}{2}$ -inch plates. The punching and shearing dies are fixed one over the other in a vertical slide, which is driven by a wheel and

FIG. 104.

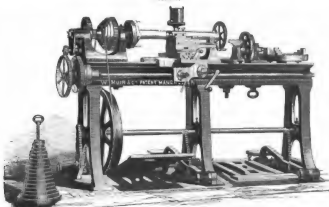


PORTABLE PUNCHING AND SHEARING MACHINE, by Mr. J. S. Hulse.

pinion, with a fly-wheel, on overhung bearings. It may be turned by hand or by power (fig. 104).

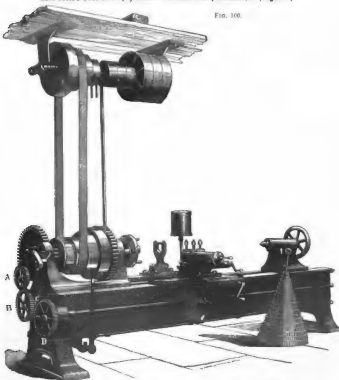
9. *Four-act. Steam Hammer.*—This is an ordinary double-acting hammer worked by hand.

FIG. 105.



SELF-ACTING FOOT LATHE, by Messrs. Wm. Muir & Co., Manchester. (Page 160.)

FIG. 106.



SELF-ACTING SLIDING AND SCREW-CUTTING LATHE, by Messrs. Wm. Muir & Co. (Page 150.)

CHAPTER VI.

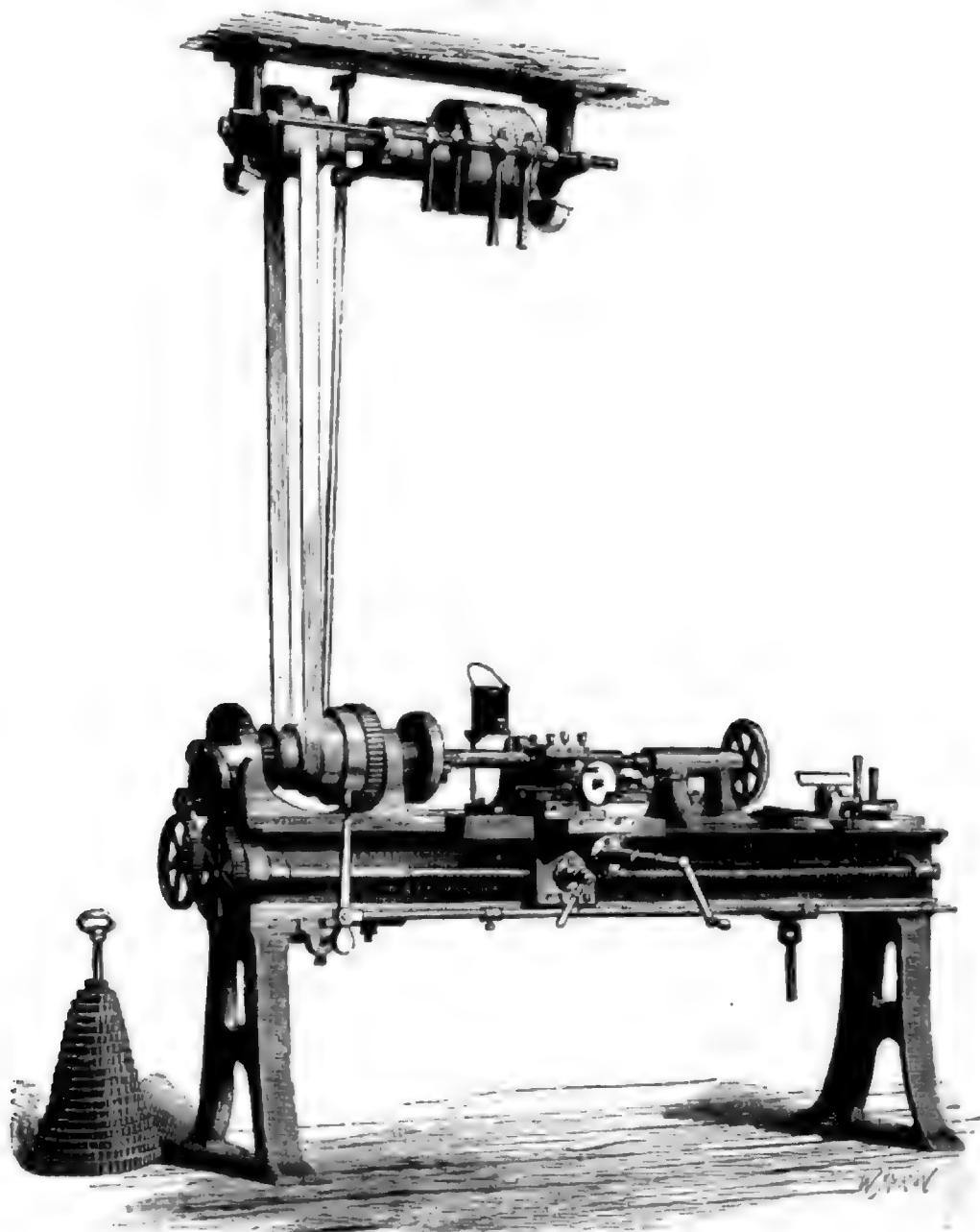
MACHINE-TOOLS EXHIBITED BY MESSRS. WILLIAM
MUIR AND CO., MANCHESTER.

Messrs. Muir & Co. exhibited a series of good ordinary tools, without pretension to elegance or fashion, plain in outline, hard in style, good in workmanship, original and sometimes happy in detail, but occasionally overdone, and withal a quaint originality and independence of treatment which command respect.

1. *Self-acting Foot-lathe*. — This lathe has 8-inch centres; it has four treddles, and is designed particularly for use on board of steam vessels, for the colonies, and elsewhere, where labour is cheap. The cone-spindle has conical steel bearings, and the lathe is fitted with a screw and change wheels for sliding and screw cutting. (fig. 105, page 149).

2. *Self-acting Sliding and Screw-cutting Lathe*. One of these lathes is made with 12-inch centres, double geared; it has a guide-screw in front of

FIG. 107.



SELF-ACTING SLIDING AND SCREW-CUTTING LATHE, by Messrs. Wm. Muir & Co. (Page 151.)

the bed, worked by change wheels for cutting screws and sliding, the guide-screw being engaged and disengaged by a clamp nut; and a rack and pinion for quick return by hand. There is also a reversing motion, by means of which right and left hand screws may be cut without changing the wheels. The cone-spindle has cast-

steel conical bearings. The transverse feed-screw of the slide for advancing the cutter has a graduated disc fixed upon the end of it, by which the attendant may regulate the depth of cut, and it has a quick drawback screw on the same axis for withdrawing the cutter. The lever by which the drawback screw is secured

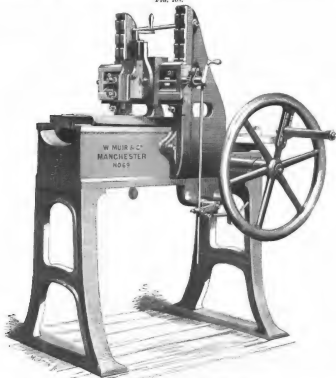
when the cutter is in action, is held in its place by a spring to prevent the pressure of the cut forcing back the cutter (fig. 106, page 149).

The other is a 7-inch lathe, similarly mounted (fig. 107, page 150).

3. *Hand-planing Machine*.—This little machine is designed for the use of philosophical

instrument makers for planing metal work from $\frac{1}{4}$ inch to 15 inches long, 15 inches wide, and 12 inches deep. It has a self-acting surfacing motion, and is worked by a continuous rotary motion with a pair of elliptic wheels, which produce a nearly uniform cutting motion, and a quick return motion of the table at treble the cutting speed (fig. 108).

FIG. 109.



HAND-PLANING MACHINES, by Messrs. Wm. Muir & Co.

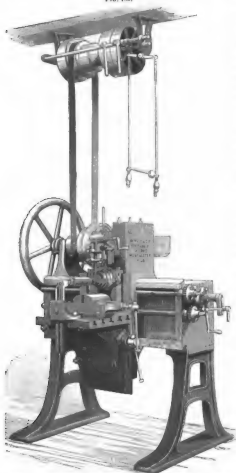
4. *Self-acting Shaping Machine*.—One machine was exhibited, having a maximum stroke of 6 inches, with 24 inches of traverse, and adapted for shaping circular work up to 12 inches in diameter. The ram is peculiar in section; unlike others, it is a flat bar on edge, sliding in adjustable "vee" bearings at top and bottom, and is encased in the headstock by which it is carried. The motion is taken from a revolving stud in the side of the driving spur-wheel, which works in a vertical slot formed in a piece fixed on the side of the ram. Thus a compact and nearly direct connection is obtained without the use of a connecting rod. The table is fitted with a vice to fix work for planing,

and a double-cone spindle, with a stay at the outer end, for circular work (fig. 109, page 152).

5. *Self-acting Slotting Machine*.—This machine has a maximum stroke of 6 inches, and takes in a wheel 3 feet in diameter. The power is delivered from a four-speed cone through a pinion and wheel to the usual slotted disc, the disc and the spur-wheel being cast in one piece. The ram works in two separate slides. The feed-motion is taken from a vertical slotted cam on the disc shaft by a connecting rod, and works the transverse and circular slides; the longitudinal feed is worked by hand (fig. 110, page 153).

6. *Self-acting Vertical Drilling Machine.*—This machine is designed for drilling and boring up to 6 inches diameter, and 10 inches deep. It has a four-speed cone with back gear. The spindle is balanced and lifted by a counter-

FIG. 100.



SELF-ACTING SHAPING MACHINE, by Messrs. Wm. Muir & Co. (Page 151.)

weight acting through a chain; it has a rack-feed. The table swivels on pivots in a carriage which slides on the frame, and is elevated by means of a worm and worm-wheel motion applied to a rack and pinion (fig. 111, page 154).

A bench drilling machine, to drill $\frac{3}{4}$ inches diameter, by hand or power (fig. 112, page 155).

7. *Self-acting Radial Drilling Machine.*—This machine is of gigantic proportions. It drills and

bores up to 10 inches in diameter and 15 inches depth, and admits an object 9 feet high. The extreme radius is 9 feet, through an arc of 190° . The sole-plate is of great length, grooved and planed. The standard is a well-fortified hollow casting bolted to it, and it carries the jib and jib-frame on a vertical slide, on which they are elevated by means of an upright screw, nut, worm and hand wheel. The jib turns in bearings on the bracket, and the spindle derives its motion from the back-gear cone behind the standard through mitre-gear and a telescopic horizontal shaft. The spindle has a rack-feed, and is traversed on the jib by a screw and hand-wheel at the extremity of the jib. The bracket carrying the driving cone is a counterfort to the standard, and a ladder-like frame of enormous strength is superimposed upon the counterfort (not shown in the illustration), to carry the intermediate driving shaft (fig. 113, page 156).

8. *Screwing Tackle.*—The dies, of which there are two, for screwing bolts, &c., are so formed that one acts as a guide and the other as a cutter. They are cut with a master-tap of a larger diameter than that of the screw formed by them,—larger by as much as the depth of one thread. The taps are formed with three flutes or grooves to form three cutting edges, which are in radial lines from the centre of the tap. The vertical angle of the threads in section is 55° for all diameters, rounded at the top and the bottom (fig. 114, page 156).

9. *Double Grindstones.*—These stones are intended to grind each other true. They may be adjusted by means of right and left screws; and, a lateral motion being communicated by cams to one of them, the surfaces of the stones are preserved true and even, and facilitate the accurate grinding of cutters (fig. 115, page 157).

CHAPTER VII.

MACHINE-TOOLS, EXHIBITED BY MESSRS. JOHN HETHERINGTON AND SONS, MANCHESTER.

The tools exhibited by Messrs. Hetherington are to be remarked for their good solid workmanship and proportions.

1. *Self-acting Slide and Screw-cutting Lathe.*—This is a 12-inch lathe, with a guide-screw employed for cutting screws, and also for sliding. The screw is embraced by a pair of half-nuts attached to the slide, put out of or into gear by a hand-lever at the front. A rack is also applied in front of the bed, for the purpose of traversing the slide by hand. The advance of the

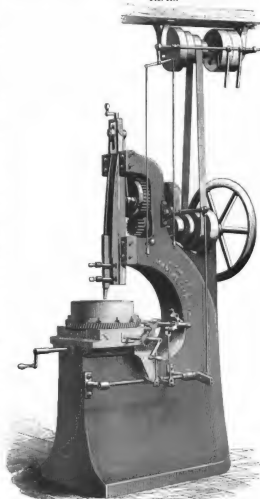
cutter, to take the proper depth of cut for sliding or for screw-cutting, is defined by means of a small-toothed detent wheel on the screw, with a spring pall; and there is a quick return to withdraw the cutter, by means of a quick-thread screw-bush, on the same shaft, of which half a turn is sufficient. A self-acting motion is applied to stop the lathe, by throwing off the belt when the slide is allowed to traverse too far in either direction. The cone-spindle has a case-hardened conical bearing, and a tail-pin to take the end-thrust.

2. *Slotting Machine.*—This machine is made for a maximum stroke of 14 inches; the frame and top are cast in one piece, a hollow casting. The cone, three-speeded, turns in bearings on the side of the frame, and drives the disc-spindle with a pinion and wheel. The motion is taken off by a connecting-rod from the disc, which is grooved for an adjustable stud-pin, to the ram, of which the elevation is adjustable by a hand-wheel and screw at the top. The disc has no upper bearing on its edge, and depends entirely on the shaft, with which the disc is cast, being much stronger than usual. The ram is guided in two distinct slides. The table has three self-acting feed-motions, and its lower straight slide is placed across the sole, instead of parallel to it, as in other machines,—the upper slide being parallel to the sole, which in other machines lies across it. This arrangement is adopted to admit of the swivel-studs underneath, to be afterwards noticed; also to admit of a long traverse across the bed, which the exhibitors consider the most convenient for shaping long articles. The table itself is solidly bedded on the slides, without overhang, the worm-wheel being as large as the table. The feed is obtained from a vertical cam on the disc-shaft, and taken down by a connecting-rod to a horizontal rocking shaft, from which it is distributed for the different feeds, with a ratchet and wheel to each. The feed-gearing is carried round three sides of the table, and is further involved with universal joints. For inclined work, the whole system of slides is turned on a pair of hinge-studs cast on the sides of the sole,—the inclination being adjusted by a screw and lock-nuts in front. For ordinary work, of

course they rest upon the solid base (fig. 116, page 158).

3. *Self-acting Radial Drilling Machine.*—The jib of this machine is movable through an arc

FIG. 116.



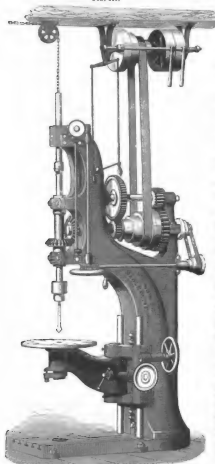
SELF-ACTING SLOTTING MACHINE, by Messrs. Wm. Muir & Co. (Page 151.)

of 280° , with a variable radius of from 2 feet 6 inches to 6 feet, and a vertical range of 2 feet. The vertical traverse of the spindle is 12 inches, and the machine is capable of taking in a piece standing 6 feet above the floor. The jib revolves on the column, and is cast in one piece with the jacket. The column and the base, also, are cast in

one piece, and the column is turned from top to bottom to receive the jib-jacket, which is bored out at both ends to fit and work upon it, both vertically and radially. The sole-plate is grooved and planed. The power is derived from a five-speeded cone with bearings on the base, behind the column, driving, by a pair of

end with the drill-carriage, but is not telescopic; it passes behind the column as the carriage moves up. The outside vertical shaft, likewise, is carried upwards with the jib, above the column. The jib is elevated by means of a rack within and attached to the jib-socket, with a worm motion. The spindle is fitted with a screw feed-motion.

FIG. 111.



SELF-ACTING VERTICAL DRILLING MACHINE, by Messrs. Wm. Muir & Co. (Page 152.)

mitres, an upright shaft within the column, which drives a parallel shaft outside, by means of a pair of spur-wheels. Motion is taken by mitres at the lower end of the upright shaft, for driving a longitudinal shaft alongside the jib, from which the spindle is driven by a pair of mitre-wheels. The horizontal shaft is carried on

CHAPTER VIII.

MACHINE-TOOLS EXHIBITED BY MESSRS. SMITH AND COVENTRY, MANCHESTER.

The tools exhibited by Messrs. Smith & Coventry combine excellent workmanship with proof of an intelligent consideration for the requirements of each tool. They comprised novelties which are likely to be found useful.

1. *Screw-cutting, Chasing, and Slide Lathe.*—This lathe has 7-inch headstocks, and combines the functions of an ordinary screw-cutting and sliding lathe, with an apparatus for chasing angular or V-thread screws. The cone-spindle has conical bearings; and, in addition, a tail-pin of large diameter and wearing surface, as a safeguard in turning heavy work, against the risk of the horizontal pressure from the shifting headstock galling or setting fast the conical bearings. The bracket for the tail-pin is applied at an angle, and may be swung on one end out of the way, when it is required to change the change-wheel on the cone-spindle. The guide-screw is in front of the lathe-bed, and is employed for cutting square-thread screws. The lock-nut for the guide-screw is in two halves, shifted horizontally. The change-wheels are made with teeth of a strong form, so as to be capable of gearing into each other for the whole depth of the teeth, or to "bottom," without gagging or breaking the teeth. The swing-plate, by which the wheels are supported, is suspended from, and swivels on, the end of the cone-spindle, the lower end being made with a circular slot, and secured with a stud-bolt and nut. Thus, the plate when loosened has no tendency to fall over; and, when fixed, is steadily secured by the fastenings at the extreme points, without the overhang incidental to the ordinary reverse arrangement, and preventing the change-wheels from forcing themselves out of gear while at work. The slide is traversed quickly back by hand, by means of a rack and pinion in front. A quick drawback motion is applied, to withdraw the cutter-slide from the thread of the screw being cut, while the saddle is being racked back. It is an eccentric motion, worked by a lever, and is so arranged that the eccentric is on the dead centre when the cutter is in its

working position, for either external or internal screw-cutting, and therefore cannot be forced back by the resistance to the cutter.

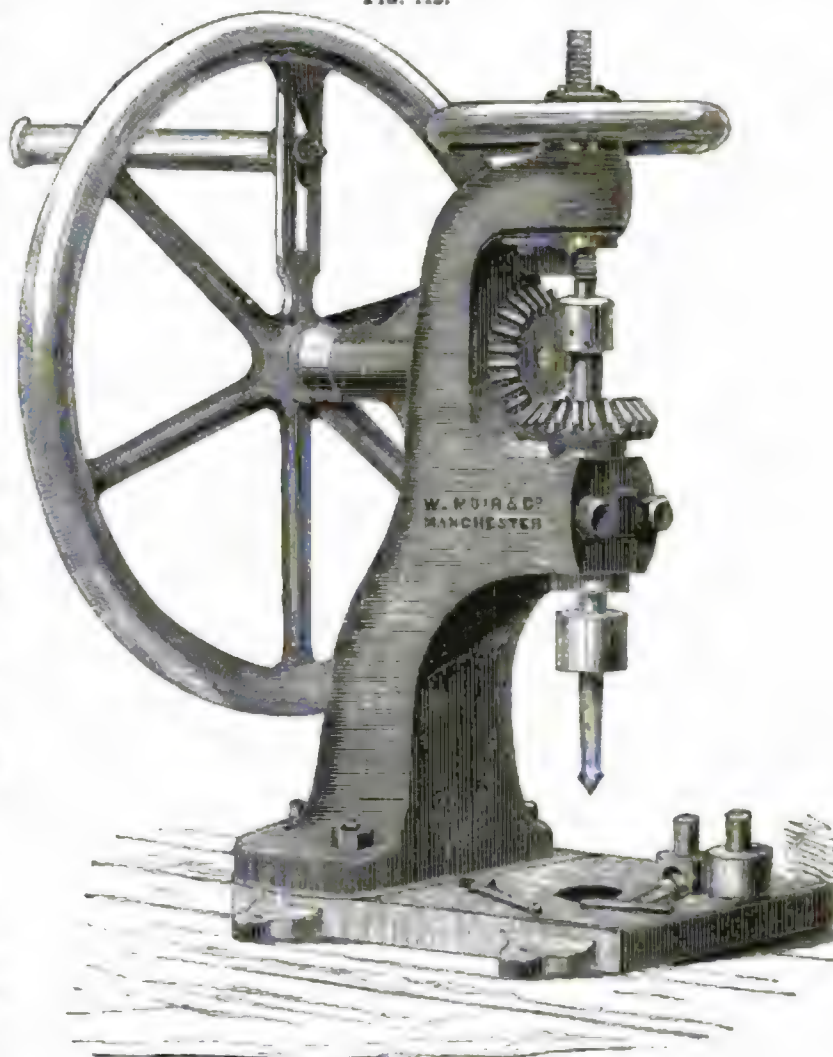
The chasing apparatus cuts screws of from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches diameter. It is placed on a saddle, which is traversed on the bed by the guide-screw, and quickly reversed by hand with rack and pinion. It consists of a circular, concentric cam-box, with three chasers, of four cutting teeth each, which are drawn to and from the centre, simultaneously, by means of a lever. There is a graduated index on the face of the box, with an adjustable stop, by means of which the chasers may be set to any required size or diameter, and against which the cam-box is retained by means of a back weight on a chain. With one setting of the cam-box, any number of screws may thus be cut to one diameter. Each screw is completed at one cut,—the chasers being withdrawn at the end of each traverse to release the saddle. The threads of the chasers are sloped off at the entering side, on the principle of the conical screwing dies, so that every successive thread in each chaser cuts successively deeper, until the complete screw is formed, whilst the thread of the screw is fairly started correctly to the pitch (fig. 117, page 159).

2. Shaping Machine.—This machine has a 10-inch stroke. The ram is driven by a slotted link, with a central connection to the ram, and a quick return. The bed is of unusually great depth in front—18 inches—to afford a steady bearing and support for the tables; and in their 16-inch shaping machine, the exhibitors carry down the bearing to the ground. There are two tables, made with vertical faces, to fix work to laterally. The machine has two feeds, for straight and circular work. The worm-wheel for one of the feeds is in two lengths, divided across the axis, adjustable for wear. There is also an adjustment to correct the wear of the hinge-pins of the cutter-box, by means of conical nuts, one at each end (fig. 118, page 159).

3. Bench Drill.—This machine is adapted for working by hand, and is also provided with a three-speed cone to work by power. It drills $\frac{3}{4}$ -inch holes, 4 inches deep, and admits objects 17 inches diameter. It has a screw-feed, worked by hand. The table is circular, and rests upon a bracket, which may be turned aside on a pivot, to make way for long articles (fig. 119, page 159).

4. Self-acting Vertical Drilling Machine.—This machine has a $2\frac{1}{4}$ -inch spindle, and drills and bores up to 8 inches in diameter. It is made with a grooved and planed sole-plate, to which the frame is bolted. The frame is a hollow casting; it has a three-speed cone, with back gear to drive the drill-spindle, placed

FIG. 112.



BENCH DRILLING MACHINE, by Messrs. Wm. Muir & Co. (Page 152.)

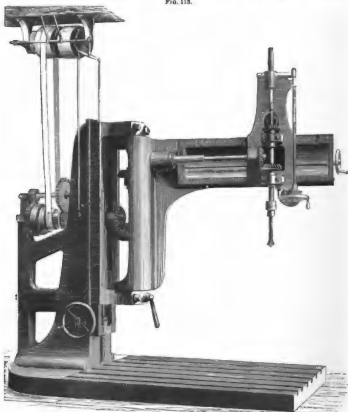
within the frame. The drill-spindle is made with conical bearings, and is fitted with a screw-feed above, with hardened steel plates between the spindle and the screw, to take the pressure of the cut, neatly and firmly let into the upper part of the frame, with bearings above as well as below the nut-wheel; it is worked by a motion from the cone-spindle through a pair of small cones behind the frame, with worm and spur gear. The hand-wheel for working the feed is fixed by friction. The table is square, with two horizontal slides; it also slides vertically on the front of the frame, adjustable by a worm and spur gear, with a nut and screw. In a more recent design, the table is swivelled to the frame at one side, and may be swung right out of the way, so as to leave the space in front of the frame entirely clear (fig. 121, page 160).

5. Self-acting Radial Drill.—The sole-plate is

grooved and planed; the standard is erected on and bolted to it at one end, and is made with a vertical slide for the jib-frame. The jib is cast with a long vertical limb, with pivots to revolve in earrings in the frame, as in Messrs. Whitworth's drill. The power is derived from a large

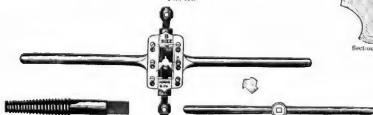
five-speed cone, and increased by being transmitted through a bevil pinion and wheel to a vertical shaft in the jib-frame, with two pairs of mitres, to a horizontal shaft in the jib, passing behind the drill-carriage. From this shaft the drill-spindle, having conical bearings, is driven

FIG. 113.



SELF-ACTING RADIAL DRILLING MACHINE, by Messrs. Wm. Muir & Co. (Page 152.)

FIG. 114.



SCREW-STOCK AND TACKLE, by Messrs. Wm. Muir & Co. (Page 153.)

by means of a pair of spurs and a bevil pinion and wheel, with a short intermediate shaft. From the same shaft the feed-motion is obtained, through a pair of small cone-pulleys at the end of the jib, turning a horizontal shaft in front of the drill-carriage; this shaft carries a travelling worm, from which, with spur gear, the spindle is lowered by a screw-feed. The feed may be worked by hand, for convenience, from the drill-carriage. The drill-carriage is traversed on the jib by hand, by means of a longitudinal screw passing behind the carriage, with a nut, and skew-gear connection: being worked by a hand-wheel at the end of the jib; also by a hand-wheel on the carriage itself, so that the workman may adjust the drill under his eye. A simple and quick lifting motion is provided for raising and lowering the jib, by means of an upright screw; it is derived from an extra pulley on the cone-spindle, which drives a pulley on a small shaft passing through the base of the standard, with a worm to turn a spur on the upright screw. When this motion is not in operation, the driving-belt must be thrown off. This machine has a radius of 6 feet, with a vertical traverse of 2 feet 9 inches, and admits an object 7 feet high under the spindle (fig. 120, page 160.)

CHAPTER IX.

MACHINE-TOOLS EXHIBITED BY MESSRS. C. DE BERGUE AND CO., MANCHESTER AND LONDON.

Messrs. C. de Bergue & Co. exhibited a number of tools remarkable for originality of invention and contrivance. The machines are compact, and they appear light; but with their lightness

FIG. 115.



DOUBLE GIRDLING MACHINE, by Messrs. Wm. Muir & Co. (Page 152.)

6. *Planing Machine.*—In this machine, of which a photograph was exhibited, attention may be directed to the very large bearing surfaces, and the obtuse angles of the “vees,” or slides for the table,—designed for preventing the possibility of galling or cutting; and to the arrangement for oiling the vees by means of small oil-boats, which are slipped into receptacles or vacancies cast for them in the table over the vees: by self-acting syphons the fresh oil is drawn to lubricate the surfaces. A quick return, at three times the cutting speed, is obtained; and the reversal of the driving-belt is performed with just the same velocity, without violence, at both ends of the traverse, by means equivalent to the arrangement applied by Messrs. Fairbairn & Co., and hereafter noticed.

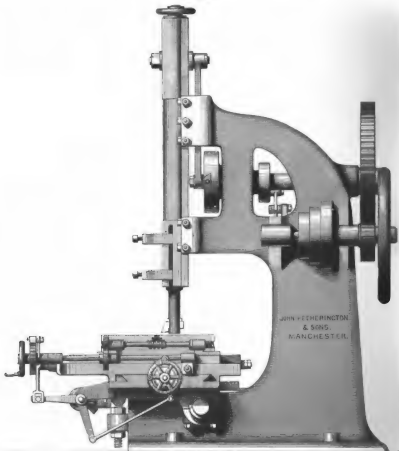
they combine great strength, and such of them as were exhibited at work—as the steam-punch—performed their duty with ease, and within a wide margin of safety.

1. *Steam-Punching and Shearing Machine.*—The chief feature in this machine is the rocking frame, which vibrates on a pivot at the base, and works the punch and the shears alternately. It is, in fact, a massive triangular lever, of which the pivot is the fulcrum, with a vertical arm, 6 feet long, to receive the power at the upper end, and two horizontal arms, 3 feet long, one on each side of the pivot, carrying the punch at one end and the upper shear at the other end. The upper end vibrating horizontally, the two lower ends vibrate vertically, as in an ordinary combined punching and shearing machine, with the slight difference that they vibrate in circular

arcs, which are, however, practically straight lines, whilst the slides of the ordinary machine move in perfectly vertical lines. This is a distinction of no practical moment, but it has acquired a certain degree of prominence by being frequently urged. The rocking lever vibrates between two massive frame castings bolted together, which give bearings for the pivot and

for the driving shaft overhead. This shaft is formed with eccentrics forged upon it, with $4\frac{1}{2}$ inches throw, turning in rectangular slide-blocks working vertically in a slot in the lever, and giving $2\frac{1}{2}$ inches vertical motion to the punch and the shears. The steam-cylinder is $9\frac{1}{2}$ inches diameter, with $9\frac{1}{2}$ inches stroke, and makes, in proper working order, 200 revolutions

FIG. 116.



SLOTTING MACHINE, by Messrs. John Ketherington & Sons, Manchester. (Page 115.)

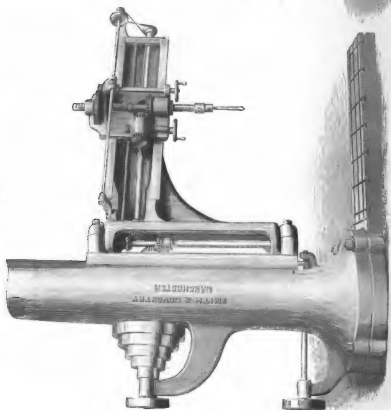
per minute. The speed of the engine shaft is reduced by means of an intermediate shaft, to make sixteen strokes of the punch and of the shears per minute.

Dispensing with the slides of the ordinary machine, the wear and tear of slides is avoided, and less driving power is consumed. The punch

and the shears are conveniently placed at the extremities of the rocking lever, and the sole of the frame is rounded away towards each side elliptically, which is convenient for workmen in getting about the machine, and handling their work. The disengaging motion for the punch may be worked instantly by a lever



FIG. 123.



SELF-ACTING RADIAL DRILLING MACHINE, by Messrs. Smith & Coventry. (Page 155.)

FIG. 124.



SELF-ACTING VERTICAL DRILLING MACHINE, by Messrs. Smith & Coventry. (Page 155.)



Figure 1. A vintage treadle sewing machine.

the 'information' and 'communication' fields. The 'information' field is defined as the study of the nature, production, distribution, use and control of information. The 'communication' field is defined as the study of the nature, production, distribution, use and control of communication. The 'information' field is defined as the study of the nature, production, distribution, use and control of information. The 'communication' field is defined as the study of the nature, production, distribution, use and control of communication.



FIGURE 1. A person reading a book.

The 'information' field is defined as the study of the nature, production, distribution, use and control of information. The 'communication' field is defined as the study of the nature, production, distribution, use and control of communication. The 'information' field is defined as the study of the nature, production, distribution, use and control of information. The 'communication' field is defined as the study of the nature, production, distribution, use and control of communication.

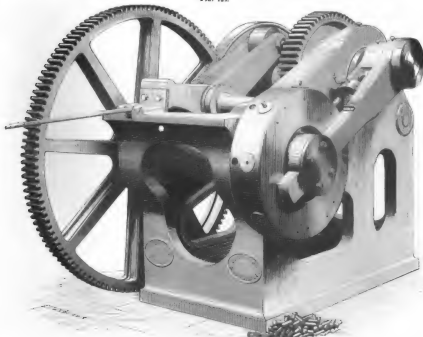
The 'information' field is defined as the study of the nature, production, distribution, use and control of information. The 'communication' field is defined as the study of the nature, production, distribution, use and control of communication. The 'information' field is defined as the study of the nature, production, distribution, use and control of information. The 'communication' field is defined as the study of the nature, production, distribution, use and control of communication.

rivets per minute up to 1 inch in diameter (fig. 124).

5. *Angle-bar Cutting Machine.*—This machine acts, by a pair of angle shears, to receive and to cut angle iron by a direct vertical motion from

an eccentric. The upper or reciprocating shear-blade is carried by a rectangular slide, connected to the eccentric by a short intermediate piece, and has 3 inches of vertical motion. By the interposition of the connecting piece, which reduces the angular action on the slide, this machine

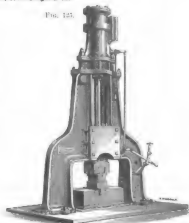
FIG. 123.



RIVET-MAKING MACHINE, by Messrs. C. De Bergue & Co.

differs from the ordinary slide-punch, in which the eccentric acts directly upon the slide. It is adapted also for cutting up scrap, and is capable of cutting bars 6 inches by $1\frac{1}{4}$ inches, or angle-iron bars 4 inches by 4 inches by $\frac{3}{4}$ of an inch thick. The motion is reduced by compactly-arranged gearing.

FIG. 125.



15-CWT. STEAM HAMMER, by Messrs. James Nasmyth & Co., Manchester.

CHAPTER X.

MACHINE-TOOLS EXHIBITED BY MESSRS. JAMES NASMYTH AND CO., MANCHESTER.

Messrs. Nasmyth & Co. exhibited a selection of steam hammers, with which the name of Mr. Nasmyth has been long and honourably associated as the inventor and original manufacturer; also some special tools and machinery.

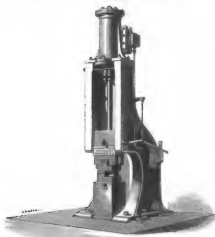
1. *15-cwt. Steam Hammer.*—This hammer is arranged for either single or double action, to be worked by hand. It is fitted with Mr. Robert Wilson's double-acting equilibrium or balanced slide-valve, which is worked with ease and celerity, so as to regulate the velocity and force of the blow, according as the nature of the work may require. The change from single action to double action, or reversely, is effected instantaneously by turning a catch fitted to the quadrant guard of the working handle. The two sides of the frame, which is of the ordinary Nasmyth form, are braced together by an iron plate on each side at the lower end of the slide (fig. 125).

2. *10-cwt. Projecting Steam Hammer.*—This hammer is arranged to be worked with single or double action by hand, with Wilson's equi-

The hammer-block is made of wrought iron. This arrangement of hammer is adapted for drawing down or tilting steel, or for any other purpose requiring a rapid succession of blows, varying in number and intensity (fig. 127).

4. *Punching Machine.*—This machine is fitted with a traversing table and a self-acting and differential dividing apparatus, and has a steam-engine attached to work it. In the dividing apparatus, a ready means is provided for varying the pitch of the rivet-holes to be punched, and punching any given number of holes in any length of plate up to 10 feet 9 inches in length, without altering the position of the plate on the table: the same number of holes, reckoning from end to end, may be punched with certainty in plates of various length, from 9 feet 4½ inches to 10 feet 7½ inches. The dividing or pitching of

FIG. 126.

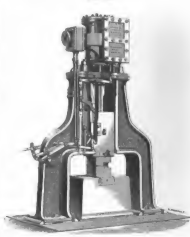


10-CWT. PROJECTING STEAM HAMMER, by Messrs. James Nasmyth & Co.

ilibrium-valve. The frame projects over the anvil to admit of long forgings being laid across the front on the anvil (fig. 126).

3. *10-cwt. Self-acting Steam Hammer.*—This hammer, like the others, is fitted for single or double action, with Wilson's equilibrium-valve. By reason of the freedom and promptness with which the valve may be worked, the force of the blow may be varied instantly from one of the utmost intensity to a mere touch, and any number of blows may be given at any rate up to 280 blows per minute. The hammer as it rises shuts off the steam by striking a cam on a lever, of which the fulcrum may be shifted to one of three positions, for different lengths of stroke.

FIG. 127.



10-CWT. SELF-ACTING STEAM HAMMER, by Messrs. James Nasmyth & Co.

the rivet-holes is effected by means of a horizontal pin-rack placed obliquely upon the bed of the machine, into which a hinged pall or stop

FIG. 128.



PUNCHING MACHINE, by Messrs. James Nasmyth & Co.

works, suspended from the table, and by which the table is shifted forward for the pitch of the rivet-holes by one pin at a time. The pitch is varied by disposing the pall at a different angle across the pin-rack, when it may be understood that the more obliquely the pall is placed, either forward or backward from zero on the index, the shorter or longer will be the pitch or traverse of the table for each pin passed by the pall. When the pointer stands at zero, the pitch of the rivet-holes is equal to that of the rack (fig. 128).

5. *Self-acting Shaping and Differential Dividing and Notching Machine.*—This machine was originally devised for notching the scale-beams of weighing-machines, and the same principle was extended to the punching machine just described. By means of approximating dividing wheels, any scale of divisions may be obtained,

FIG. 129.



SELF-ACTING SHAPING AND DIFFERENTIAL DIVIDING AND NOTCHING MACHINE, by Messrs. James Nasmyth & Co.

and may be increased or diminished in length to the smallest degree, so that any standard scale may be made with the greatest exactness, and to any required variation in length, in the proportion of $2\frac{1}{2}$ inches less or more on 3 feet, with a simple index-adjustment. The machine is applicable as a slide-rest for cutting screws of any pitch, and the pitch may be varied to any extent, so that any standard pitch may be obtained from any true leading screw (fig. 129).

6. *Model of Cotton-baling Press.*—This machine is designed for packing cotton into bales, and is intended for use in India and other distant countries, where compactness of bales for transport is a primary object. The table is 4 feet by 16 inches wide, and has a lift of $11\frac{1}{2}$ feet, compressing a bale into 18 inches deep. It has a three-cylinder hydraulic press, with rams 9 inches in diameter, of which the middle ram is worked quickly to save time, and lifts the two others with it, which are followed up by

water, until, when the final pressure is applied, all the three rams are put to work by a hydro-static pressure of 3 tons per square inch. The press is capable of compressing 400 lb. of cotton into a space of 8 cubic feet at the rate of 100 bales per day of 10 hours (fig. 130).

7. *Equilibrium Slide-valve.*—This valve, which has already been mentioned, is the invention of Mr. Robert Wilson, of the firm of the exhibitors. It is made either single-acting or double-acting, and possesses the advantages of balanced valves, in being more easily worked and maintained than steam-valves generally used.

8. *Screw-Propeller.*—This propeller was invented by Mr. Wilson during the period from 1812 to 1819, and was tested by him in 1821. From a pamphlet printed by Mr. Wilson, it appears that, in 1827, it was tested before several leading members of the Dunbar Mechanics' Institution, and other scientific gentlemen, and was shortly afterwards submitted to the Lords of the Admiralty by the late Earl of Lauderdale, but without avail. It was tested in 1828 before a Committee of the Highland Society of Scotland, and in 1832 before a Committee of the Royal Scottish Society of Arts. It was again submitted to the Lords of the Admiralty in 1833, and was rejected as an objectionable plan of propelling vessels, independently of practical difficulties (fig. 131).

FIG. 130.



COTTON-BALING PRESS, by Messrs. James Nasmyth & Co.

FIG. 131.



SCREW-PROPELLER, by Mr. Wilson.

LEEDS MACHINE-TOOLS.

CHAPTER XI.

MACHINE-TOOLS EXHIBED BY MESSRS.
P. FAIRBAIRN AND CO., LEEDS.

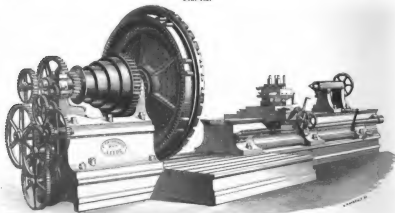
The machines exhibited by Messrs. Fairbairn & Co. are solidly, substantially, and thoroughly constructed, with an unsparing use of material. They are generally efficient machines, well considered in the details.

1. *Self-acting Slide Break-Lathe*.—This is a treble-gearled lathe; it receives in the break objects not exceeding 7 feet in diameter and 6 feet wide. It is adapted for sliding, screw-cutting, boring, and surfacing objects from 2 inches to 7 feet in diameter. The base-plate extends the whole length of the lathe, and is planned and grooved for the cutter-rest. The driving headstock, 21 inches high, is placed upon a solidly formed standard, and bolted down to the base-plate. The bed for carrying the saddle and cutter-rests, and the following headstock, is moveable on the base-plate by rack and pinion, and is fixed by bolts and nuts. There are three changes of speed-gear for the face-plate:—direct from the cone-pulley, from the back gear, and from a third shaft with gearing to turn the face-plate by means of a pinion gearing into an internal spur-wheel on the back of it. In adopting the internal wheel, the face-plate is turned in the same direction with all the three speeds, avoiding

thus the inconvenience of applying a cross-belt for the slowest speed. The internal wheel is bolted on the back of the face-plate in eight segments. The nave of the face-plate is turned out and let over the collar on the cone-spindle, to which it is bolted; this makes a stiff and secure fastening, which, for a large overhung face-plate, is of prime importance. The saddle is formed with T-grooves for fixing work by crosshead bolts when boring; it is traversed by the guide-screw on the outside of the lathe-bed, which derives its motion from the cone-spindle through a system of change-wheels at the back of the fixed headstock, turning a shaft which passes from end to end of the base-plate in a sunk channel, and which turns the guide-screw by gearing at the other end.

An ingenious reversing motion, now much employed in machinery, is provided at the end of the cone-spindle for reversing the guide-screw and the saddle through the change-wheels.

FIG. 132.



SELF-ACTING SLIDE BREAK-LATHE, by Messrs. F. Fairbairn & Co., Leeds.

A couple of carrier-pinions, hung on a moveable frame, are employed to transmit the motion from the pinion on the end of the cone-spindle to the change-wheels. By a suitable movement of the frame, one of the pinions is thrown into gear, whilst the other is out of gear, to transmit motion for the forward traverse of the saddle. By a contrary movement, the other carrier-pinion is brought into gear as an additional intermediate, and the motion is reversed.

The surfacing motion is derived from the screw by means of an "elastic cone" carried by the saddle, which, by a suitable application of hand-power, tightly embraces the screw and converts it into a shaft, locking the saddle at the same time without strain. The surfacing is thus, with the assistance of some gearing, worked

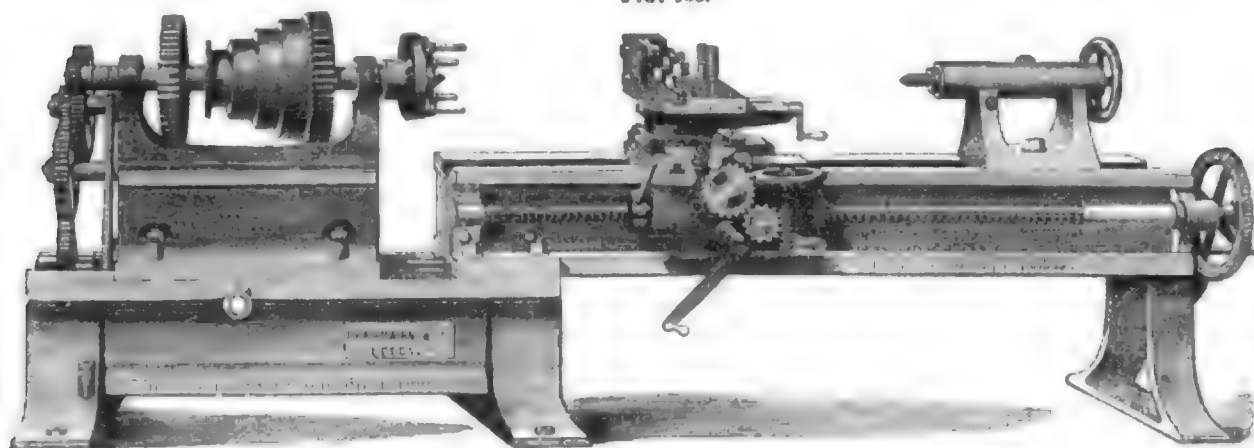
direct from the guide-screw, obviating the wear and strain of a worm-wheel on the screw, and dispensing with a rack. The spindle of the loose headstock is locked by means of a worm and segment acting through an eccentric upon a steel die.

The loose headstock is firmly bolted to the bed by four cross-headed bolts in two T-shaped grooves formed on the upper surface of the bed. A special standard may be bolted to the projecting part of the sole-plate to carry surfacing and cutter-slides, which may be detached from the saddle for sliding and surfacing large work in the break; and for these, self-action may be had by an overhead-motion from an eccentric on the cone-spindle working a ratchet-wheel on the surfacing screw (fig. 132).

2. *Slide and Screw-cutting Lathe*.—This lathe has 10-inch centres, and is made with a sliding gap. It is otherwise an ordinary slide and screw cutting lathe. The fixed headstock is bolted to the bed by four bolts in T grooves, and it may be shifted to close the gap, the driving-cone on the intermediate shaft shifting likewise on a key. The slide-rest, in surfacing large diameters, may thus be brought close to its work without destroying its accuracy. The surfacing motion is derived from the guide-screw on the same principle as in

the large lathe. The slides are removable from the saddle to make the lathe useful as a boring machine. The bearings of the cone-spindle are conical, of hardened steel, and worked in hardened steel bearings; and, it may be added, conical steel bearings are adopted for sizes of lathes up to 12-inch centres; above 12 inches, the spindles have cylindrical bearings running in gun-metal. By means of the change-wheels, a variety of cuts for traversing may be had at the rate of from 16 to 50 cuts per inch run. The change-wheels

FIG. 133.



SLIDE AND SCREW-CUTTING LATHE, with Movable Gap, by Messrs. P. Fairbairn & Co.

are fitted with a reversing-motion like that described for the break-lathe, when the centres are above 12 inches high (fig. 133).

3. *Double Stud-Lathe*.—This lathe is made with 6-inch centres, and is designed for turning studs, bolts, and other plain work up to $2\frac{1}{2}$ inches diameter and 12 inches long. Two driving headstocks, placed in the middle of the bed, are fitted with steel spindles having conical necks working in steel bearings, and with two sets of fast and loose pulleys, each with a belt-fork, giving two speeds. A casehardened worm on the spindle works a casehardened wheel and drives a clutch, which, by a system of small mitres and screw, traverses the saddle in either direction. The clutch-reversing lever, the hand-wheels for working either saddle by hand, and the belt-forks for stopping, or starting, or changing the feed, are all at the ready command of the boy in attendance. Clement's drivers are fitted to the chucks.

4. *Self-acting Radial Drilling Machine*.—This machine has a steel spindle $2\frac{1}{4}$ inches diameter, and the radial arm is movable in an arc of 320° . It is double-gearred, which is advantageous for facing and boring, and is arranged to work single-gearred when drilling holes of a small size. It will bore up to 7 or 8 inches diameter, and will drill from the solid $2\frac{1}{2}$ inches diameter. The base-plate is rectangular, and made with crosshead or T grooves; and planed on the upper side, so that objects to be operated upon may be adjusted with facility. It is made of a

convenient width, that a pit may be made on either side for large work, to take advantage of the full circuit of the drill-spindle. The jib or radial arm turns upon a central column or standard solidly bolted to the base-plate, having turned bearings at the top and bottom to receive a jacket or envelope embracing it for its whole height, which turns upon it, and is made with a vertical slide to carry the jib or radial arm.

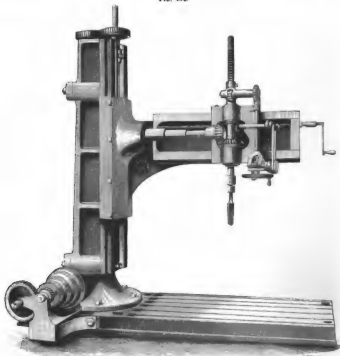
The driving gear is similar to that of a back-gear lathe, and is bolted upon one edge of the base-plate. The drill-spindle is driven by a pair of bevels from a telescopic sliding-shaft, passing in front of the jib, driven by mitres from an upright shaft brought down from the top of the jib-slide. This external upright shaft is turned by spur-wheels from an internal upright shaft which rises from the foot of the column and is driven by mitres from the cone-spindle. The feed is given by a rack-spindle and pinion worked by a couple of worms and wheels, and made self-acting by a motion through a couple of small cone-pulleys from the spindle. The traverse of the spindle-carriage on the jib is effected by a screw turned by hand from the end of the jib. In larger machines of this class, an additional means of traversing adjustment is provided close to the drill-spindle on the unoccupied side, so that the attendant need not leave the work to set the drill by the end handle. The jib may be set by power to any height, from 30 inches to 6 feet, above the base-plate, by means of a vertical screw working in a long nut on the jib, the motion of which is obtained by an excentric on the central upright

shaft, working by a double pall a wrought-iron ratchet-wheel keyed on the vertical screw, and thrown out of gear when not required (fig. 134).

5. *Self-acting Radial Drilling Machine (second system).*—This machine, of a smaller size than the other, has a steel spindle $1\frac{3}{4}$ inches diameter. It is double-gearred, and driven from an intermediate shaft at the base, so that it may

be swivelled completely round the central column. The base is novel, having a deep side, 30 inches high, grooved and planed like the horizontal surface, for fixing objects, which, for many purposes, must prove of great convenience. The range of the drill, radially, is 42 inches from the centre, and it is designed for drilling a $1\frac{1}{2}$ -inch hole out of the solid without the aid of the back gear, and to bore up to 4 inches diameter. The jib is cast

FIG. 134.



SELF-ACTING RADIAL DRILLING MACHINE, by Messrs. F. Fairbairn & Co.

on the jacket, and swings at a fixed height above the base, not being adjustable vertically. The driving gear may thus be made comparatively direct. The horizontal shaft, driving the spindle by mitres, is located above the jib; it is not telescopic, and reaches freely over the column, and is driven by mitre-wheels direct from the central upright shaft. The spindle is firmly guided by and revolves in a tube cast on the drill-frame; the feed is given by means of a screw bearing end to end on the top of the spindle, which is grooved at the side, and works on a key to prevent it turning round. The nut on the screw is turned by gearing from a hand-wheel, or from a variable self-acting motion derived by cone-pulleys and mitres from the spindle, and so the spindle may be raised or lowered. This machine

is of the nature of a special tool, and must prove serviceable in large works (fig. 135).

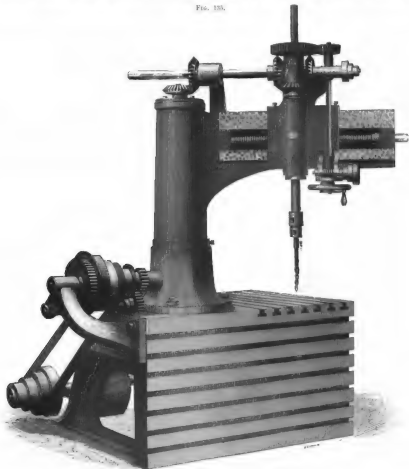
6. *Self-acting Vertical Drilling Machine.*—This is a large machine, with a $2\frac{3}{4}$ -inch steel spindle for drilling and boring holes up to 12 inches diameter, with a vertical feed of 24 inches; it takes in objects 5 feet in diameter. The frame is cast hollow, and in one piece with the sole-plate. The drill is double-gearred, and the intermediate driving-shaft is hung at the base behind the frame. The table is circular, with a central pivot let into a bracket, and secured by a large nut and set-screws; the bracket is supported by, and turns upon a column keyed and fastened to the principal frame in front of it. The table is thus movable horizontally in two ways,—centrally

on its own axis, and radially about the column; and it may be swivelled aside to make way for large or heavy work upon the base-plate. It is obvious that the needful over-hang of the drill-spindle from the frame is comparatively increased by the advance of the swivel column, which limits the clear space for objects placed on the table; the column is, however, removable with the table when greater

space is required. The table is elevated by means of a worm and gearing, with a vertical rack bearing upon the column, embedded in the socket of the bracket, and swivelling with it (fig. 136, page 170).

7. *Self-acting Planing Machine.*—This machine is made for planing work not exceeding 6 feet by 6 feet by 20 feet long, and is arranged

FIG. 135.



SELF-ACTING RADIAL DRILLING MACHINE, by Messrs. P. Fairbairn & Co.

with three independent cutter-boxes. The table is traversed by a rack and pinion worked by bevil-gear from the driving-shaft, which lies parallel to the machine at its base, and thus the machine can be put down in a line with lathes and other tools, under the line of shafting, or it

can be placed alongside a wall, and driven by the shaft against it. The bevil gear is double, comprising a motion for reversing at quick speed, with two fast and one loose pulley, driven by the strap; the gearing is good, but it is in the way of the attendant. The

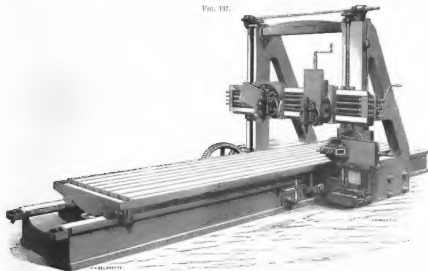


8. *Self-acting Planing Machine (second size).*—This machine is designed like the larger one, and planes objects not exceeding 30 inches wide, 30 inches high, and 5 feet long.

9. *Shaping Machine.*—This machine is constructed with treble gear, for a maximum stroke of 24 inches. In large machines of this kind, a deficiency of power is frequently felt for the long strokes, where the power is derived direct from the cone-pulley, whilst for light work, often put on the machine to keep it going, the requisite speed cannot be obtained without vibration. To avoid this result, double-gear driving-cones are employed by the exhibitors, connected to the

pinion-shaft from which the disc or crank-wheel is driven. For light and finishing strokes, the cone-pulley works single gear of slight ratio; and for heavy work, the cone works another range of speeds through treble gear. The bed is of the ordinary form, but is made deeper than usual, which is a good feature, to afford ample stiffness and support for the overhanging tables with their loads, particularly when in a low position with large objects on them, and to resist the pressure of the cut. The tables are elevated by means of a rack and worm-wheel instead of by a screw, by which means the weight of the table causes no additional resistance by friction, which arises more or less

FIG. 137.



SELF-ACTING PLANING MACHINE, by Messrs. P. Fairbairn & Co.

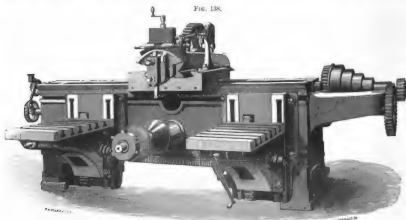
when the table, with slackened fixings, presses forward on the screw. The tables are shifted horizontally, out of the way, by means of a rack on the lower edge of the bed. The ram or cutter-slide is moved by a crank-motion, with a quick return applied to one side of the ram. The crank-pin or revolving stud is fixed on the side of a spur-wheel moved from the pinion-shaft, and it works in a vibrating slotted lever, when the slower forward motion for the cut is produced while the pin is performing the upper part of its revolution farther from the centre of the slotted lever; whilst, for the faster return-motion, the pin returns below, nearer to the centre: the slotted link is connected to the ram by a connecting link at the side. The cutter-box is made with straight and circular slides to feed vertically, and to plane hollows and rounds, with self-acting motions. The mandril for circular work is turned as usual by a worm-

shaft; two openings are made for the mandril at different elevations in the side of the frame, one above and one below the worm-shaft, in either of which positions the mandril may be turned, and thus works of large diameter may be shaped (fig. 138, page 172).

10. *Shaping Machine (small size).*—This machine is designed, with $3\frac{1}{4}$ inches stroke, for shaping small work, as nuts, bolt-heads, keys, and small levers. There are two headstocks on one bed,—one for flat work only, the other for circular work. The stroke is given from a shaft with a crank-pin, on which there are two pairs of driving-pulleys, fast and loose, of two sizes, to give two speeds, each with a belt-fork, and driven by a drum on the main shaft. The work for the flat machine is fixed on a table by vice-jaws, and is made to traverse upon a slide by a self-acting motion from a ratchet-wheel and

screw. The table may be shifted vertically to a small extent. For shaping nuts on this table, a small dividing apparatus is used; and the exhibitors consider that, with the attendance of a boy, and the ease with which the cutters are ground, nuts may be shaped more cheaply in

this machine than in others more completely designed for nut-cutting. The other headstock, for circular work, has the same driving appliances. The cutter-box is supplied with an additional horizontal slide for shaping the flat portions of small levers, and for adjustment.

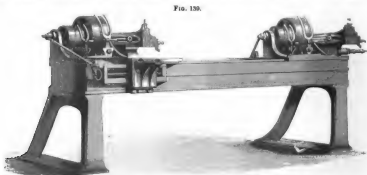


SHAPING MACHINE, by Messrs. P. Fairbairn & Co.

The mandril is formed with a taper hole like that in a lathe-spindle, to receive different-sized chucks, screwed up by a nut against a collar (fig. 139).

11. *Self-acting Slotting Machine.*—This machine is designed, with a 12-inch stroke, for light or heavy work, and for this purpose is

arranged with double driving gear, which is thrown out, and the cone-pulley alone used for quick and finishing strokes. The frame and bed are cast hollow, in one piece. The cutter-slide, or ram, is held by continuous slides on the frame, to confer stiffness and durability. The crank-disc is made with slots across the face, to receive cross-head bolts for fixing and adjusting



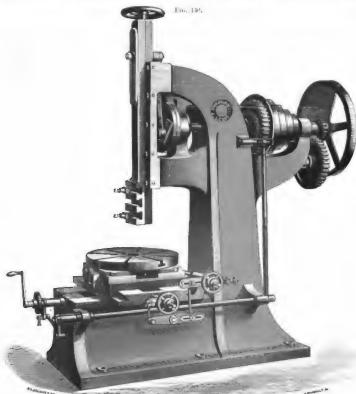
SHAPING MACHINE (SMALL SIZE), by Messrs. P. Fairbairn & Co.

the pin to various lengths of stroke. The disc obtains a bearing with its circumference on the framing above, by which a more nearly direct resistance is opposed to the strain of the cut, than when the strain is opposed by the shaft-

bearing behind the disc. It is stated also that there is less wear of the shaft-bearings. The ram is counterweighted by a mass of metal in the fly-wheel on the end of the disc-shaft. The table is circular, and is movable longitudinally.

dinally, transversely, and by rotation. The feed-motion in all of these directions is derived from a vertical slot-cam formed on the spur-wheel keyed on the disc-shaft, and is taken down by a lever and connecting-rod to a rocking-shaft alongside the base, from which, at different points, a separate set of ratchets and gear is applied to work each feed. These feeds, being at hand, may be thrown off at a moment's notice. In working the straight cuts, but little variation of the feed is required; but for circular

cuts, the rate of feed is affected by the radius of the cut, and in mixed work requires to be frequently adjusted. To obviate inconvenience and delay in such operations, the circular feed is supplied with separate slotted levers, by means of which a feed of from one to eight or nine teeth of the ratchet may be taken by it, whilst the straight feeds take one to three teeth. The table is adjustable to an incline, for inclined work, on the worm-shaft as a fulcrum, when it is kept rigid between lateral flanges. Thus



SELF-ACTING SLOTTING MACHINE, by Messrs. P. Fairbairn & Co.

the lower compound slides are kept rigid, and universal-joints are dispensed with in the feed-levers. The ram may be raised or lowered by means of a screw and bevil-gear, and as the slide-frame for the ram is continuous, the cutter may be elevated to work upon high objects which would not pass between the table and the lower jaw of the frame (fig. 140).

12. *Small Slotting Machine.*—This machine has $3\frac{1}{2}$ inches of stroke, and is specially adapted

for doing a variety of work often done by hand, or at a loss of time by large tools. The machine is driven simply by means of fast and loose pulleys, with belt-fork brought within easy reach of the boy attending at the front. The cutter-slide is balanced, and is carried in a swivelling frame, by which the cutter may be set to slot at any angle required. The table is circular, with compound slides, to feed in three directions, like the larger machine. The transverse motion is 9 inches long, and



13. *Circular Shearing Machine*.—This machine is designed for cutting sheet-iron from the thickness of tin to $\frac{3}{4}$ inch thick. It consists of two circular cutters, both driven by gearing, the lower cutter being adjustable upwards or downwards in an excentric tube, by means of a worm and wheel. The distance apart to which the cutters are set is a little less than half the thickness of the plate to be cut. Thus, the angles formed by the cutters with the surfaces of the plate admit of the work being readily drawn in. A small table is placed in front of the cutters to carry the work, and is made with a T groove and a movable stud on which, as a centre-pin, circular work is guided, and a truly circular form is cut. The machine is portable, and may be driven by hand or by power.

14. *Pantograph Cutter-forming Machine*.—This machine is designed for cutting or forming the circular cutters employed in wheel-cutting and dividing machines. It is built on a compact frame about 18 inches square, to be placed on a bench. The work to be cut is fixed on a mandril in a small headstock, with a dividing plate, and compound slides for adjustment. The cutter is a small conical mill on a vertical spindle placed in a frame. The spindle is turned by means of a spur pinion on its lower end, driven by another spur which derives its motion from an endless cord; and the necessary traverse for the horizontal cut is communicated to the spindle-frame, which swivels on the axle of the second spur, by means of a system of levers forming a parallelogram, of which the arms are in length as two to one. These levers carry a friction-roller twice the diameter of the conical mill, which is guided round a template twice the section of the cutter. From this a similar motion of half the range is communicated to the conical mill or spindle-frame, and the process is repeated until the work is finished.

15. *Surface-Plates*.—Three surface-plates are exhibited, in the construction of which special attention has been given to the form of the ribs on the under-side for strengthening and supporting the plate. A deep elliptic rib is placed in the middle of the plate, with straight ribs radiating from the circumference of the oval. Equal areas of surface are comprehended between the neighbouring ribs, for the purpose of keeping the casting free from inequality of tensional strain. The plate rests on three screws with spherical heads, having "tommy-holes," by means of which the plate may be levelled with accuracy.

CHAPTER XII.

MACHINE-TOOLS EXHIBITED BY MESSRS.
SHEPHERD, HILL, AND CO., LEEDS.

Messrs. Shepherd, Hill, & Co. exhibited a limited, but select, number of genuine tools, judiciously designed, and honestly and soundly constructed, on well-tried patterns that have long borne the test of experience, with some excellent practical appliances.

1. *Self-acting Slide and Screw-cutting Lathe*.—This lathe is made with 8-inch centres. The fixed headstock has a four-speeded cone with back-gear. The cone-spindle has conical bearings, and the play is taken up by lock-nuts at the back bearing. There is also a tail-pin at the end of the spindle to receive the thrust. The back-gear shaft works in excentric bearings, and is turned out of gear with the cone-spindle by reversing the excentrics. The chuck is fitted with Clement's driver. The fixed headstock is adjustable to an angle by means of lateral set-screws between the sides of the lathe-bed, to throw the centre out of line, and facilitate the turning of tapering or conical pieces.

The slide is worked by a guide-screw, in front, for cutting screws; and by means of a rack, also in front, for ordinary sliding. The rack and the pinion working into it are placed directly in a vertical line below the point of the cutter, to confine the strain and minimize the wear of the sliding surfaces. The rack-motion of the slide is derived from a slotted driving shaft at the back of the lathe-bed, driven by a pair of small three-speeded cones, of which the upper one is hung free on the end of the back shaft of the fixed headstock, the shaft being used only as a stud; it is moved by spur-gear from the cone-spindle. A connection is made from the lower cone by a worm-wheel, through a cross shaft and suitable spur gearing with the rack. From the same back shaft a feed motion for surfacing is taken off by the transverse screw. The slide is fitted with two disengaging motions, or friction-couplings, one on the surfacing screw, and the other on the cross sliding-shaft. These couplings are made by concentric cones, which may be instantly locked or freed by hand, in front, by turning a handle half or quarter of a turn. The usual mode of reversing, by an inverted weighted lever at the back, is inconvenient and unsafe if the cutter enter the work too far, as it may spoil the piece; but the friction-coupling gives way before dangerous cuts can be made. The workman knows by experience what degree of tightness to put upon the cones for light and for heavy cuts; in short, they are a safety-coupling, and practically are found very convenient. The feed-motion of the slide is reversed by means of a couple of intermediate pinions in a swing-frame worked from the front, and operating in the manner already described in Messrs. Fairbairn's break-lathe.

The guide-screw is reserved exclusively for cutting screws, and is engaged with the slide by means of a long half-nut which is let down upon it, and disengaged by hand by means of an excentric motion. The slide may be quickly reversed by means of the rack-gearing, turned by a handle in front.

2. Self-acting Break-Lathe.—The fast headstock of this lathe, 14 inches high, is made and furnished with back-shaft for sliding, with the necessary gearing and connections to the slide, and similarly to the 8-inch lathe. The lathe has an expanding gap or break, the fast headstock being fixed upon a short block with a projection, upon which, between two guides, one end of the bed may slide parallel to the headstock. The feet of the bed slide at the same time upon base-plates. The bed is moved, for adjusting the width of the gap, by means of a hand-screw at the end of the bed. The shifting headstock has an eye cast on it, by which it may be temporarily pinned to the slide, and shifted along the bed by means of the hand traversing-gear applied to the slide.

3. Planing Machine.—This machine is made for planing objects not exceeding 5 feet long and 2 feet square. It is fitted with a single cutter, having self-acting traversing and vertical feeds, operated through an upright shaft at the side. The table is fitted with the ordinary double tappet-motion for reversing. It is driven by a duplicate rack and pinion, and has a quick return motion of three times the cutting speed.

4. Slotting Machine.—This machine is made for a maximum stroke of 12 inches. The ram is carried in two distinct slides, and is worked by a shifting stud in a disc, as in the other machines. The elevation of the ram is adjustable by a screw and hand-wheel at the upper end. It is driven by a five-speeded cone-pulley in bearings on one side of the frame, with an overhung fly-wheel on the spindle, and a pinion to drive the disc-shaft. The disc is let partially into the frame to obtain a bearing on its circumference. The frame is in one hollow casting, heavily proportioned. The table is circular, with the usual self-acting feed-motions, for which the motion is derived from a horizontal cam on the disc-shaft, through an upright rocking shaft, from which by means of small mitre wheels and slotted levers the motion is adjusted and conveyed to a horizontal rocking shaft, and thence distributed by levers, ratchets, and gearing to the slide-screws and the worm. The worm-shaft is steadily supported, without overhanging, in two end bearings. The table is well supported on the slides; but, for inclined slotting, the whole system of slides, being hinged on the base, may be raised from it in one mass.

5. Bench Shaping Machine.—This machine has a maximum stroke of 6 inches. It has two

headstocks on one bed,—one for shaping flat surfaces, for which the piece is held in a vice; the other for circular cutting, for which the piece is held on a double-cone spindle, supported at the outer end by a stay. The rams are driven each by a crank-pin in a slotted disc, adjustable for the stroke, and a connecting-rod in the centre line of the ram.

CHAPTER XIII.

MACHINE-TOOLS EXHIBITED BY MESSRS. SMITH, BEACOCK, AND TANNETT, LEEDS.

Messrs. Smith & Co. exhibited a number of machines, chiefly special tools, in some of which the aid of the template is introduced, for turning and shaping contour forms by self-acting means. The machines are substantially made, though they are occasionally heavy and ungainly, and are constructed in the old style, with a number of pieces bolted together, that might have been advantageously cast in one.

1. Self-acting Slide-Lathe with Template Motion.—This lathe has $8\frac{1}{4}$ -inch centres: it is self-acting in all its motions, and constructed to fulfil all the ordinary duties of a slide-lathe, with the addition of a template motion in front of the bed, designed to guide the cutter so as to describe a uniform curve, for turning the longitudinal swell of a connecting-rod. The template may, of course, be changed for different swells, to suit the variety of connecting-rods, coupling-rods, links, and other work.

The ordinary parts of this lathe are fitted in the old manner. It has cylindrical bearings for the cone-spindle, and a tail-pin to take the thrust. The traversing slide-motion is derived from the back-shaft of the headstock with a pair of small three-speed cone-pulleys, and a reversing motion by means of intermediate spur-wheels in a swing-frame worked from the front, as described in Messrs. Fairbairn's lathe. The traverse feed-motion is thrown out of gear with a clutch and upright weighted lever, which is pushed over, and slides the intermediate spur out of gear with its pinion. The upper portion of the shifting headstock is shifted transversely on its base by means of a screw, out of the centre line of the bed, for angular or conical turning. To fix the spindle in the headstock, the latter is slit open for a few inches at the end, and has two edge-flanges drawn together by a screw, so as to clasp the spindle.

2. Self-acting Slide Screw-cutting and Cotter-turning Lathe.—This lathe has 7-inch headstocks, with the ordinary motions for sliding, surfacing, and screw-cutting, and a special motion for turning the round edges of gibs and cotters. The

work is reciprocated in half-round evolutions, by means of an eccentric on the back-shaft of the headstock, which works a rack to and fro, gearing into a pinion on the back of the faceplate, by which the rocking motion is produced. The feed is provided by a motion from a zigzag groove in the rack, to work a ratchet from which, with suitable connections to the sliding-shaft at the back, the traverse of the slide is given.

The guide-screw for cutting screws is placed at the front of the bed, and the rack for sliding at the back of the bed.

3. *Buffer-Lathe*.—This lathe is made with a central fixed headstock and two shifting headstocks; with two slides, one of each on each side, for turning two buffer-rods at once. The fixed headstock has a three-speeded cone and dead centres, and the power is transmitted by gearing to two spur-wheels, one on each end of the cone-spindle, in the positions usually occupied by faceplates. The slides have self-acting surfacing and sliding motions derived from the cone-spindle, with the addition of a template motion to each for sliding the curved and angular portions of the buffer-heads: one attendant works both divisions of the lathe.

4. *Self-acting Shaping Machine*.—This machine is designed for shaping keys, cotters, and general light work. It has three cutter-heads on one bed, driven separately, with a maximum stroke of 5 inches, and 14 inches lateral traverse. The middle head is fitted with a table and a double-cone spindle for circular shaping; the end heads are fitted for straight cutting only. The tables are raised or lowered by means of hand-screws. There are no vices for fixing plain work on the tables. This machine may be managed by one attendant.

5. *Slotting Machine*.—This machine has a maximum stroke of 20 inches. It is designed for slotting the cranked axles of locomotives, and can cut a slot in the nave of a railway wheel 7 feet in diameter. For cranked axles it may cut out the webs between the crank-arms with two tools at once, fixed on the ram, and may also be applied to shape and finish the crowns and sides of the crank-arms with two tools at once, the axle being secured on the table in a vertical position.

The frame and the sole are cast separately in hollow or box castings, and bolted together with a vertical joint. The driving cone-pulley has five speeds, and has its bearings on one side of the frame. The ram has three long vertical grooves in front, to receive the holding bolts for one or two cutters, at any required elevation. The elevation of the ram is adjustable by a hand-wheel and screw at the top. The ram is carried in two distinct slides, and is driven by a connecting-rod from a grooved disc, for which a gun-metal edge-bearing is introduced on the upper

side. The disc-shaft is driven with a quick return, with the aid of an intermediate shaft which is driven by the cone-spindle. The shaft carries two pinions, which gear alternately with two spur-segments on the disc-shaft, one of which performs the down-stroke; the other, for the up-stroke, is a flatter segment, and the driving pinion is eccentric, giving a quick return as by ordinary gearing. The table is upwards of four feet in diameter, and has the usual self-acting motions, of which the longitudinal and transverse feeds are performed by means of a pair of screws to each, one on each side of the centre line of motion. The circular feed is performed with a single worm: probably a duplicate worm on the other side of the table would be an improvement.

The feed is taken down from a vertical cam on the disc-shaft, through an upright shaft, to a slotted lever on the lower end, from which the feed is regulated and distributed through shafting and gearing to the table.

6. *Connecting-Rod Slotting Machine*.—This machine is designed to shape and finish the edges of connecting and coupling-rods for locomotive engines, &c., by a combination of self-acting motions. There are two headstocks on one bed, with self-acting motions longitudinally, transversely, circularly, and by template, the work being secured on a continuous shelf or table in front. The headstocks have separate overhead and driving motions. The template to be applied contains the contour form of the object to be shaped or slotted, and the tool moves freely to this form. There is a considerable quantity of gearing employed in the construction of this machine; and the cutter is not fixed direct to the ram in the usual way, but is excessively overhung in a cluster of details appended to the base of the ram, for carrying out a self-acting circular motion of the cutter.

7. *Rifling Machine for Cannon*.—This machine is adapted for rifling guns with any number of grooves, with any degree of twist, regular or irregular. It was constructed from the designs of Mr. John Anderson, superintendent of the Royal Gun Factories, Woolwich, and is a first-rate application of exact and scientific principles. The whole machine, with means of fixing the gun to be rifled, stands upon a long and solidly-formed baseplate cast in one piece, 28 feet long and 4 feet wide. The rifling mechanism occupies one end, and the gun the other end, of the baseplate. The rifling-bar, 5 inches in diameter, and the sliding carriage by which it is forwarded, rest upon a solidly-constructed bed, like a lathe-bed, fixed upon the base-plate, the bar turning in two bearings, one upon the carriage and the other a stationary bearing upon the end of the bed, near to the muzzle of the gun, through which the bar slides longitudinally. The carriage is traversed by a longitudinal screw $5\frac{1}{2}$ inches

in diameter, with double-acting bevil-gear and three belt-pulleys for forwarding and reversing, as in Messrs. Whitworth's planing machines. The rifling cutters are fixed on the far end of the bar, and the revolving or twisting movement of the bar is derived by means of a pinion with machine-cut teeth of fine pitch, keyed on the near end, which is turned by a rack that slides transversely on the carriage, like an ordinary cross slide. The traverse of the rack-slide is communicated from a "tangent-bar," similar in function to a template, consisting of a parallel-sided bar laid horizontally at an angle to the carriage-bed, and embraced by a pair of friction or guide rollers hung at the end of the rack-slide. As the carriage traverses upon the bed towards the gun, and the cutters advance along the bore, the rollers likewise traverse upon the tangent-bar; and, through them, the bar, by its angularity, gradually pushes the rack-slide across the bed, the slow motion of which is converted by the pinion into a very slow revolving motion of the rifling-bar, generating the required degree of rifle for the bore of the gun. The proportions for any degree of rifling are matters of simple calculation. The tangent-bar may be set by a hand-screw to any angle horizontally with the bed of the machine; and there is a refinement by which the wear of the pinion may be taken up to prevent backlash, the pinion being made in two lengths, divided across the axis, and adjustable so that the teeth of the one may slightly overrun those of the other half, and extinguish the slackness.

The motion for regulating the radial projection of the cutters and the depth of the rifle-grooves in the bore, is derived from a pair of "master-bars," or templates placed alongside the bed, which are traversed alternately, one in each direction, by a roller on the end of a weighted lever attached to the carriage. The weighted lever is connected with the cutters by means of a rod passing right through the rifling-bar, which is hollow, having a conical termination at the far end to act upon the cutter-holders in the bar, and project or withdraw them as required for the formation of the groove. The weighted lever and roller in travelling along the upper bar project the cutters according to the outline of the bar, and produce the exact figure in depth or profile required to be given to the groove.

The rifling-bar generally used for the larger guns has eight cutters in action at once, and the gun is so placed in bearings as to be readily turned on its axis by self-acting gear. The workmanship and general appearance of this machine are most praiseworthy.

8. *Universal Shaping Machine.*—This is another of those exceptional and complicated machines in which simplicity, on the one hand, and due proportions between belt-power and the work to be done, appear to have been overlooked. The three-speeded driving-cone is placed at the summit of the machine, between six and

seven feet from the ground, which is a wrong position. The cone has pulleys 5 inches wide, of which the largest is 20 inches in diameter, for the purpose of driving small circular cutters. The machine is designed to shape by circular cutters the curves or irregular forms of pieces usually shaped by hand labour. It has a massive frame of enormous strength, the lower part of which is similar to the bed of a shaping machine, having a table attached by slides to one side. The table, 12 inches in diameter, may be swivelled vertically, like the cutter-box of a planing machine, to any angle, and is provided with a dividing-wheel and change-wheels. It has a self-acting horizontal motion, and a circular motion with worm turned by hand. There are, in addition, a four-screwed chuck, a small bedplate with headstocks and dividing apparatus for fluting and grooving, and a slide-vice for gripping the work. Nuts are cut suspended in the small headstocks just named, the cutter dragging the nut. Should the cutter be allowed to get blunt, the strain would probably break the miniature headstocks.

CHAPTER XIV.

MACHINE-TOOLS EXHIBITED BY MESSRS. MACLEA AND MARCH, LEEDS.

Messrs. Maclea & March, Leeds, exhibited a number of tools of ordinary construction. A *7½ inch slide-lathe*, with back gear, has a rack in front of the bed for sliding, with a traversing motion from a back shaft. The cutter-holder swivels in the slide-rest. Second, a *double-face-plate wheel-lathe*, with 6 feet 4 inch face-plates, to turn 6 feet wheels. The face-plate is weakened by four deep crosshead grooves, radially across the face, for fixing the chucks. The holes formed through the face are very irregular and unequal. The "vees" for the slides are tightened by means of slips inserted between the bevil surfaces, and drawn up by thumb-screws. Complete accuracy can scarcely be ensured with such fittings. Third, a *shaping machine* of 12 inches stroke, in which, to compensate for the insufficient depth of the bed, the table-frames are stayed at the foot by a cross slide-plate bolted to the base. This is a useful addition, and no doubt some other exhibited shaping machines would have been better for it. There are two tables, each having two vertical planed faces for fixing pieces laterally, —very handy. The ram is driven by a slotted link with a quick return. The feed is taken from a double inclined plane on the back of the ram, through a lever resting on and moved by it,—primitive. Fourth, an ordinary *slotting machine*, of 6 inches stroke. Fifth, a *planing machine*, with deeply grooved "vees," and irregular bolt-holes in the table.

CHAPTER XV.

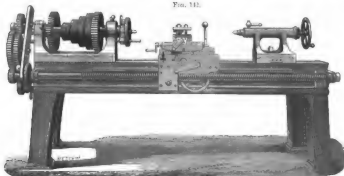
MACHINE-TOOLS EXHIBITED BY MESSRS. JOSHUA BUCHTON AND CO., LEEDS.

Messrs. Buchton & Co. exhibited four machines, of which a brief notice may be given.

1. *Self-acting Sliding and Screw-cutting Lathe*.—This lathe has 8-inch centres. The

cone-spindle has conical bearings, with lock-nuts, and a tail-pin in addition, which for convenience is fixed vertically. A spur is fixed on the spindle inside the tail-pin, and gives motion for two feeds,—first, through change-wheels to the front for the guide-screw; second, by turning a wheel attached to the first of a pair of small cone-pulleys, to give motion to the worm-shaft at the back for sliding, with a reversing motion by intermediate wheels in a swing-frame.

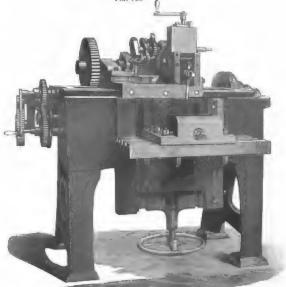
FIG. 141.



SLIDING AND SCREW-CUTTING LATHE, by Messrs. Joshua Buchton & Co., Leeds.

FIG. 142.

The sliding feed is thrown out of gear by means of the ordinary sliding clutch and weighted levers, to engage or disengage the worm-wheel. The centre of the guide-screw is placed at a distance of 6 inches from the side of the bed; and with such a great leverage—at 11 inches from the centre line of the bed—the oblique strain and friction in moving the slide must be very considerable. The swing-frame for the change-wheels is hung on the end of the screw, and must increase the strain on the bearings of the screw. The shifting headstock has a transverse adjustment for conical turning. The bed is formed with a gap or break, for which, when not in use, a filling-piece is supplied and inserted, making a flush and continuous bed (fig. 142).



SHAPING MACHINE, by Messrs. Joshua Buchton & Co.

2. *Shaping Machine*.—

This machine has 9 inches stroke. It has two adjustable tables for flat work, and a conical mandril for circular work.

The ram is reciprocated from a slotted link with a quick return, worked by an adjust-

able stud in a revolving lever on the second shaft, with a short connecting-rod attached centrally to the ram, and at the near end, so that the fore part may not be strained downwards by the pressure from behind. The feed-motions for the traverse of the ram, and the rotation of the double-cone spindle for circular work, are neatly derived from the lower end of the vibrating slotted lever, by a rod working a rocking-shaft, from which ratchets are brought to bear upon one or other of two spur-wheels on the ends of two horizontal screws, which give the two feeds. A self-acting feed for revolving the cutter-box, for hollow shaping, is derived from the reciprocations of the ram, by means of which a couple of tappets, alternately struck, work a ratchet-motion on the worm-shaft, on which the worm turns the worm-wheel on the pivot of the cutter-box (fig. 143).

3. *Slotting Machine*.—In this machine, of 9 inches maximum stroke, the ram works in two slides, and very much overhangs the slotted disc by which it is driven, which also overhangs its bearing, without any assistance from an upper bearing, to reduce the leverage strain. The cone is overhung upon its spindle behind the frame. The table is fitted with the three self-acting feed-motions, derived from a vertical slotted cam, in the face of the spur-wheel on the disc-shaft.

4. *Punching and Shearing Machine*.—This is a machine of extremely large and heavy dimensions, such as is used in ship-building yards where the heaviest class of iron vessels are constructed. It is driven by compound gear, with a double reduction of speed, and is made for punching $1\frac{1}{4}$ -inch holes in $1\frac{1}{4}$ -inch plates, and for shearing $1\frac{1}{4}$ -inch plates, at a maximum distance of 2 feet from the edge of a plate. The shears are placed obliquely, so as to clear and cut bars of any length. The machine has a third appliance in the middle for shearing angle-iron, up to 7 inches broad on a face, with a knee-jointed motion and a stop-motion. The angle-iron to be cut is laid flat on one of its sides, and the shear descends in an angular direction. This appliance is of great utility for shearing the ends of deck-beams that cannot be cut on the ordinary mode of fixing angle-iron shears.

CHAPTER XVI.

MACHINES EXHIBITED BY MESSRS. GREENWOOD
AND BATLEY, LEEDS.

Messrs. Greenwood & Batley exhibited a number of machines for working both in metal and in wood. They are designed for special purposes,—chiefly for the manufacture of rifle-

muskets, on the American system,—and abound in ingenious special contrivances, the prevailing feature being the circular cutter for “milling.” The business of designing and specializing machine-tools is an arduous one, and is most creditable to the pioneers of machinery who can be found to undertake the task.

1. *Straight Milling Machine*.—In this machine the circular cutter is fixed on a spindle driven by a wheel and pinion, of which the teeth are cut diagonally, forming portions of many-threaded screws, working into each other. The object of this formation of teeth is to produce smooth working. The journals of the spindle are adjustable vertically, and very accurately fitted, and move simultaneously by screws. The spindle is held endways by means of hardened cast-steel collars, which are ground with the greatest care. The circular cutters are ground up, after having been hardened, to the exact shape, and the cutting edges are matured by the same process. They are so shaped as to be capable of being frequently sharpened without softening, for the sake of economy of maintenance. The table is self-acting, with a self-acting stop-motion to act when the work is finished, and prevent the risk of breakage. This machine, with “fixings,” performs nearly one-fourth of all the shaping required for a rifle.

2. *Profile Milling Machine*.—This machine is adapted for copying irregular figures, with a circular cutter on an upright spindle, carried by a vertical slide. A steel copy of the form required to be produced is fixed on a table, and the machine being put in motion, a steel tracer of the same size as the cutter, on a parallel upright spindle carried by the same slide, is held by means of a hand-lever with a universal joint, in contact with the copy, whilst the table is moved by the other hand of the operator, so as to traverse the length of the article to be cut. By a species of parallel motion, all the intricacies of the shape of the copy are followed by the tracer, whilst the cutter shapes the work to the exact form of the copy. Lock-plates, hammers, butt-plates, trigger-guards, &c., are shaped upon this machine with accuracy and despatch; and the tedious process of filing to “former” is almost entirely dispensed with.

3. *Rifling Machine*.—This machine is designed for rifling musket-barrels, and is similar to those made by the Exhibitors for the Small-Arms Factory at Enfield. The bed is placed a few degrees off the level. At the lower end there are suitable bearings and dividing apparatus to receive the barrel. At the upper end the rifling bar is carried, and is turned by a pinion and transverse sliding rack, regulated by a tangent bar, to give the twist. The grooves in an Enfield rifle are progressive in depth from the muzzle to the breech:—that is, they are deepest

at the breech, and they run out towards the muzzle, where the cut is scarcely 1-100th of an inch in depth. To produce this effect, the cutters are gradually forced radially outwards, being made to ascend an inclined plane by the agency of a screw on the end of a square rod within the rifling bar,—the screw turning into the end of the rifling bar, inasmuch as the rifling bar revolves in giving the twist, whilst the square rod remains at rest in connection with the feed-gear. There is a self-acting variable motion, which regulates the length of traverse of the saddle on the bed, to give the stroke of the cutter, in proportion to the depth of the cut:—beginning at the breech with a short stroke, and gradually increasing the length of stroke till it amounts to the whole length of the barrel. A considerable saving of time is thus effected, in limiting the length of traverse to the length of each successive cut.

4. *Moulding-table for Shells.*—This table is constructed for moulding 40-pounder Armstrong shells, with its accompanying core-table. It was fitted up at the Royal Laboratory department, at Woolwich Arsenal, and is in principle the same as tables constructed by the Exhibitors for making spherical shot and shell for the Royal Arsenal.

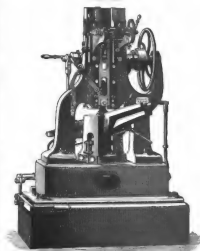
5. *Percussion-cap Machine.*—This machine was arranged by Mr. Wm. Whitehill, and made for military purposes at the Royal Arsenal. The caps are formed from "crosses" punched out of sheet copper by six punches on the ends of plungers worked by an eccentric. The crosses are dropped down slides, and are caught by a second series of six punches, by which they are forced into dies, and finished to the exact form of the cap. The caps are delivered from the machine ready to receive the charge of percussion-powder, and are manufactured at the rate of 35,000 per hour.

6. *Boot-pegging Machines.*—These machines, the invention of Mr. White, are designed for pegging or riveting on the soles of boots and shoes. The smaller machine is for cutting the pegs from wire. By one stroke the wire is cut diagonally, and by the return stroke square across, thus producing two diagonal-pointed pegs. The pegs are deposited in two feed-boxes, with spiral grooves into which the pegs are delivered against the action of a coiled spring. From this machine the boxes, when filled, are removed to the second, the pegging machine. The pegs are driven by a punch through a guide at the mouth of the feed-box into and through the sole, and clinched at the point upon an iron last inside.

7. *File-cutting Machine.*—This machine resembles a steam-hammer in general appearance. It is provided with a vertical slide, carrying a chisel at the lower end; the upper end is subject to the action of a flat spring governed by a

cam, actuated by a ratchet-wheel and paul, to adapt the strength of the blow of the chisel to the varying breadth of the file. The "blank" to be cut is placed upon a zinc bed on a travelling slide, which rests upon a semicircular bed mounted on trunnions which turn in swivelling journals,

FIG. 144.

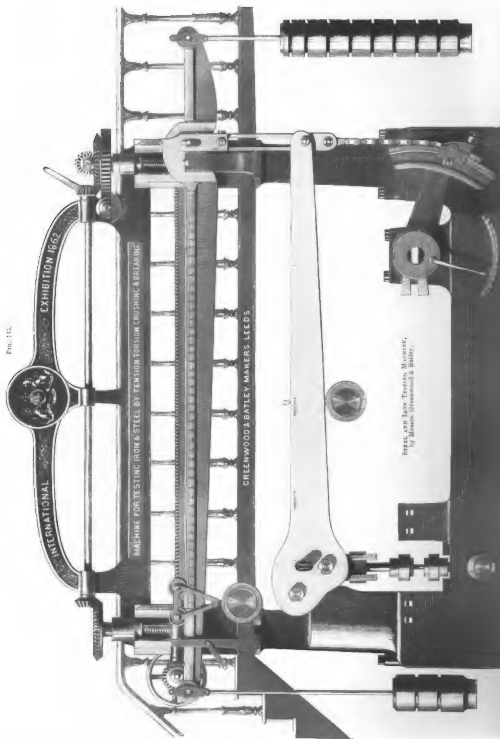


FILE-CUTTING MACHINE, by MESSRS. GREENWOOD & BATLEY, LEEDS.

so that the blank may be presented at the desired angle to the chisel. The blank is held parallel to the edge of the chisel by means of a weighted lever (fig. 144).

The machine makes from 700 to 1,000 cuts per minute, and is said to produce about five times the quantity of work done by hand-cutting. It is remarkable also that cutting chisels in the machine cut five times as many files as can be cut with them by hand without resharpening; which appears to arise from the fact that the chisel is driven into the blank, and withdrawn in a straight line, without any of the rubbing action which takes place in hand-cutting, when the edge of the chisel is rubbed a short distance along the surface of the blank until it comes in contact with the tooth last made, which is the only guide the hand-cutter has to produce regularity of cut. The machine-cut files are found to be as good and valuable as the best hand-cut files.

8. *Wire-testing Machine.*—This machine, originally arranged to test the tensile strength of music-wires for pianos, harps, &c., has since been employed by telegraph-cable makers, card-makers, and others, when a correct test of the strength of wire is of importance. The range of this machine is from 30 lb. to 3,000 lb. It registers the breaking-point with accuracy.



9. *Steel and Iron Testing Machine.*—For testing tensile strength and crushing resistance up to 180,000 lb. It will tear asunder, or will crush, a 1-inch square bar of cast steel; and it acts by means of a weight, with a leverage of 400 to 1. The centres are of hardened cast steel, most accurately ground up. The sliding weight is shifted by a screw pitched in correspondence with the scale, turned by a division-wheel, indicating increments of 10 lb. of pressure. The breaking weight of cast or hardened metals may be tested, also the torsional strength of bars (fig. 145).

CHAPTER XVII.

MACHINE-TOOLS EXHIBITED BY MESSRS. FOX BROTHERS, DERBY.

The machines of Messrs. Fox are good in workmanship, and are old in design.

1. *Screw-cutting Lathe.*—This is a small self-acting lathe, 9½-inch centres, for screw-cutting, sliding, and surfacing. The headstocks are strongly stiffened by deep ribs. In the fixed headstock the "back gear" is placed in front of the cone-pulley, for which there is not any apparent reason. The guide-screw is placed in front of the lathe-bed for screw-cutting, and a rack is placed at the back for sliding, in connection with a worm-shaft moved from the headstock by a pair of cone-pulleys. The shifting headstock is adjustable laterally on its own base, out of line, for conical turning.

2. *Planing Machine.*—This machine planes objects not more than 5 feet 6 inches in length, 22 inches wide, and 20 inches high. The "vee" slides are high-pitched and narrow, the ridges being on the bed and the hollows on the table,—the reverse of what every other tool-maker does; and there is an obvious difficulty in keeping the surfaces lubricated without a continuous supply of oil. The driving-gear, for which bevil-gear is employed, is provided with a quick return, barely twice as fast as the cutting speed, though most other makers increase the return to three times the cutting speed. The belt-pulleys being at right-angles to the bed of the machine, the bed may be ranged in line with the shafting. A self-acting connection is made for the vertical feed of the cutter, through a ratchet-motion attached to the upper end of the screw.

3. *Vertical Drilling Machine.*—The frame of this machine is a hollow casting with the sole-plate cast in a piece with it. The sole-plate is extended behind the frame to carry the intermediate shaft and pulleys. The driving gear has a five-speeded cone with back gear. The drill-spindle slides in and revolves with a tube with cylindrical bear-

ings and caps. It has a spindle-rack vertical feed, self-acting, but with no means of adjustment. The table is circular, bolted at the centre to a bracket. It has two slide-motions, vertically and horizontally, worked by hand. The machine is designed to drill holes up to 1½ inches diameter and 8 inches deep.

LONDON MACHINE-TOOLS.

CHAPTER XVIII.

TOOLS EXHIBITED BY MESSRS. HOLTZAPFFEL AND CO., LONDON.

Messrs. Holtzapffel & Co. have been long and justly famous for the first-rate quality of their workmanship and the perfection of the instruments of their manufacture. They exhibited an interesting collection of mixed machinery, comprising machine-tools, edge-tools, instruments, and printing apparatus.

1. *Plain Foot-Lathe.*—This lathe, with 5-inch centres, is adapted for mathematical and other light work, with division-plate, screw-adjusting index, and set of chucks, including a surface-chuck tapped full of holes, with a set of bolts of various lengths, clamps, lifting-blocks, and rectangular block for fixing work at right-angles to the surface of the chuck.

A very useful although not well-known die-chuck for holding pieces from ¼ to 1 inch diameter, has a double V slide divided in halves longitudinally; a single die is fitted in an opening in the slide, and may be reversed or removed to suit the size of the work, which is grasped between the die and a short screw tapped into the two divided ends of the slide. When the screw is tightened to fix the work, it at the same time tends to separate the two halves of the slide, and thereby fixes both work and slide at the same instant, either concentric or eccentric, as may be wished. When required, steam power is applied to these light lathes by fast and loose pulleys on the crank shaft; the lathe is driven by the foot for delicate purposes, with no other preparation than slipping the hook on the crank.

2. *Foot-Lathe, with Slide-Rest.*—This lathe is very similar to the previous one, with a sliding rest in addition, in which the main screws are covered to exclude shavings and other loose matters. A drilling and shaping apparatus is mounted upon a bracket, clamped at any required angle upon the slide-rest, and having a vertical slide, the faceplate of which carries a cutter-spindle with quick or slow-motion gearing, that may be placed either vertical or horizontal. The spindle carries either drills or circular cutters of suitable forms for grooving,

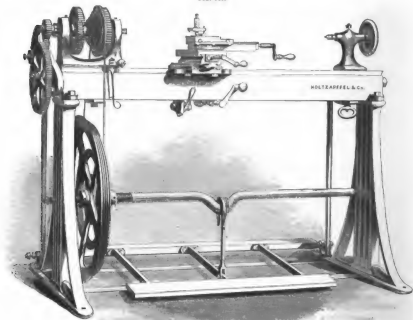
facing, shaping, or wheel cutting. The combination of the vertical slide with the two horizontal slides of the rest, the choice of position of the bracket, and the dividing plate of the lathe head, allow of the drills or cutters being presented to the work in any required direction, and by the employment of cutters of suitable shapes, enables a great variety of regular and irregular forms to be readily produced.

The driving-gear for communicating motion to the cutter-spindle consists of a frame fixed on

the back board of the lathe, and carrying two shafts with driving pulleys keyed to slide along the shafts; a tension pulley with adjustable weights, and a pair of guide-pulleys swivelled to lead the band in any required direction.

3. *Self-acting Foot-Lathe*.—This lathe has 6-inch centres; the fixed headstock is geared in the ordinary manner, and fitted with dividing plate and index. The guide-screw is placed within the bearer, and the clasp nut is closed by two links connected to a short curved lever

FIG. 146.



SELF-ACTING FOOT-LATHE, by Messrs. Holtzapfel & Co., London.

beneath, and its position is secured by a detent, not shown in the figure. The saddle-plate has grooves for the reception of the slide-rest, and itself slides as usual upon a dovetail fitting, which does not extend beyond the face of the bearer. An inverted rack is attached to the back face of the bearer with the driving-pinion beneath. The crankshaft is screwed and fitted with nuts, to traverse the foot-wheel to the required positions for the different speeds, and a counterpoised treadle is connected by a plain hook to a single-throw crank (fig. 146).

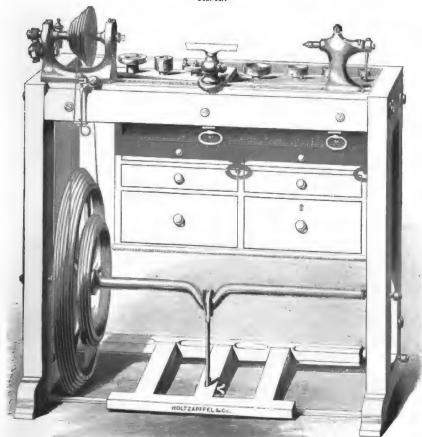
4. *Slide-Lathe for Amateurs*.—This lathe, with 6-inch centres, is adapted for both plain

and ornamental turning, and has the slow-motion gearing fitted within the mandril pulley. This is a very compact arrangement, although somewhat less powerful than the usual external gearing. The general construction of this lathe is similar to the one immediately previous; and for ordinary works in metal, the same sliding rest is employed, in which various cutting-frames are mounted; and for cutting very coarse spirals, the guide-screw and mandril are driven from the saddle-plate by a winch-handle, the motion being communicated by a pair of bevil-wheels sliding along a grooved shaft fixed in front of the lathe-bearer. The shaft carries a pinion gearing into a wheel fixed

on the right-hand extremity of the guide-screw. These coarse spirals for ornamental works are generally of a figured section, and are cut with revolving tools, mounted in a frame that admits of the cutter-spindle being placed at any required angle. The cutters are driven from an overhead motion, suspended from standards attached to the lathe-frame.

5. *Screw-Mandril Foot-Lathe.*—This lathe has 5-inch centres, and is for amateur use, with a nest of drawers beneath the backboard for containing chucks and other apparatus. The lathe-head is fitted with the screw-mandril motion for cutting short screws, in which the mandril slides endlong through its collars under the control of a short guide-screw fitting on the back project-

FIG. 147.



SCREW-MANDRIL FOOT-LATHES, by Messrs. Holtzapffel & Co.

ing end of the mandril. A series of half nuts are cut around the edge of a circular plate to match the different guides, and they are thrown into or out of action by an eccentric. The screw-mandril principle is very generally employed by the Tunbridge ware-turners for cutting short screws in soft woods, and it is also used for cutting many of the ordinary iron and brass screws commonly used in joinery (fig. 147).

6. *Screw-Mandril Foot-Lathe for Ornamental Turning.*—This lathe has 6-inch centres, and is fitted with a numerous assortment of apparatus for plain and ornamental turning, contained in a separate cabinet. This includes about fifty chucks for fixing works—oval, excentric, and dome chucks; with a variety of cutting-frames, fitted into a receptacle in the sliding rest, including drilling instruments, with figured

drills for fluting and moulding, vertical, horizontal, universal, internal, eccentric, and elliptical cutting frames, carrying revolving cutters of various forms, the whole of which are driven from the overhead motion. The work under operation generally remains stationary, while each cut is being made with the revolving tools, under the guidance of the slide rest, and the position of the work or cutter is shifted after the cut. The combination of the motion of the works and cutters, together with the varied shapes of the cutters, allow of the production of

FIG. 148.



ECCENTRIC CUTTING-FRAME, by Messrs. Holtzapffel & Co.

a great variety of forms, comprising nearly every combination of the straight line, circle, and ellipse.

The slide-rest is fitted with guides for turning curved lines, stops to determine the traverse of the tool, screw-cutting apparatus, with change wheels, applicable to spindles up to about 7 inches rise, either on cylindrical, conical, or flat surfaces. A modification of this apparatus gives a reciprocating motion to the lathe mandril, producing waved surfaces on the work under operation.

Several works of an ornamental character in hard wood and ivory were exhibited in illustration of the performances of this class of lathe apparatus, and a few figures are illustrated which have been traced by some of the apparatus. These will serve to show the general character of the details employed in the ornamentation of the plain surfaces of the various objects, and will at the same time indicate, in

a small degree, the capabilities of some of the chucks and cutting-frames; but these figures being limited to mere lines traced by the point of a tool, are necessarily inadequate to represent the more elaborate effects produced by figured

FIG. 149.



FIG. 150.



PATTERNS produced by the Eccentric Cutting-Frame.

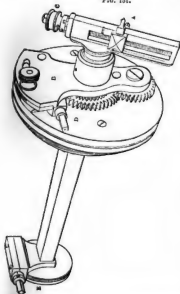
tools, more especially when employed in the formation of solid objects of artistic character, which are of course totally unsuited for direct application to surface-printing.

7. *The Eccentric Cutting-Frame.*—This frame (fig. 148) has a square stem fitted to the receptacle of the sliding rest; the spindle passes through the stem, and carries at the one extremity a pulley for the band, at the other end a tool slide with micrometer head to the screw, which determines the distance of the cutter from the centre of the instrument, and the depth of the cut is regulated by the sliding rest. Figs. 149

and 150 show some few patterns produced by the combination of the excentric cutting-frame with the movements of the sliding rest and division plate.

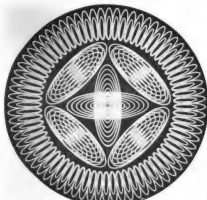
8. *The Elliptical Cutting-Frame.*—This frame (fig. 151) is capable of producing ellipses of all proportions, from a right line to a circle, by the

FIG. 151.



ELLIPTICAL CUTTING-FRAME, by Messrs. Holtzapffel & Co.

FIG. 152.

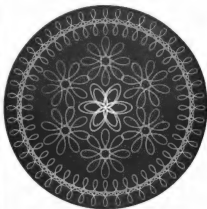


PATTERN produced by the Elliptical Cutting-Frame.

combination of two circular movements in opposite directions, the one of which travels at double the angular velocity of the other. This

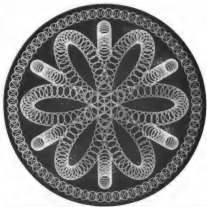
is effected by the train of wheels seen on the front of the instrument, which is so arranged that the excentric frame carrying the tool A makes two revolutions to the right while the radial flange B makes one revolution to the left. The proportions of the ellipse described by the tool depend upon the relative degrees of eccentricity given to A and B by the screws C and D; and the ellipses may be arranged in any required angular position by the worm-wheel and tangent-screw E. The power of the instrument to place the ellipses at any angle is illustrated by fig. 152. Some modification of a four-looped epicycloidal figure, produced by changing the proportions of the front wheels, is illustrated by fig. 153. The

FIG. 153.



PATTERN produced by the Elliptical Cutting-Frame.

FIG. 154.



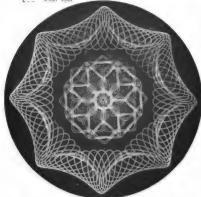
PATTERN by the Excentric Chuck and Excentric Cutting-Frame.

border consists of four-looped figures intersecting each other; the inner circle consists of six figures, in each of which the four-looped figure is doubled,

to make a figure of eight loops, by placing the two figures of four loops intermediate to each other, and the central figure consists of twelve ellipses intersecting at the centre.

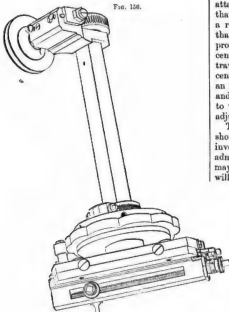
The excentric chuck is frequently employed in conjunction with the various cutting-frames. One combination of the excentric chuck with the excentric cutting-frame is shown in the hexagonal pattern in fig. 149, and another in

FIG. 155.



PATTERN produced by the Elliptical Cutting-Frame with the Excentric Chuck, &c.

FIG. 156.



ROSE CUTTING-FRAME, by MOWERS, Holtzapffel & Co.

the looped pattern of fig. 154, and one result of the combination of the elliptical cutting-frame with the excentric chuck is shown in the outer pattern of fig. 155, the inner pattern of which results from a modification of the four-looped pattern produced by the elliptical cutting-frame, when the eccentricities of A and B are in the proportion of one to eight, from which a nearly square figure results, as seen in the diagram.

The oval chuck and spherical chuck are similarly employed in conjunction with the various cutting-frames, in order to place the work in the required position for the operation of the cutting tool, to which the required motion is given by the cutting-frame, the work remaining stationary during the operation.

9. *Rose Cutting-Frame.*—This frame (fig. 156) produces patterns, on surfaces, exactly similar to those made by the rose-engine with vibrating headstock; but the rose cutting-frame is applicable to any lathe, and may be employed to produce rose-engine patterns in exactly the same manner as the excentric and elliptical cutting-frames produce the circular and elliptical patterns, and they may be combined in the same general manner. The instrument is fixed in the sliding rest, and motion is given to the pulley A , mounted on a tangent screw that drives the worm-wheel B , fixed on the end of the spindle which passes through the square stem, and carries round with it the slide C upon which it is clamped, the tool D attached to the back of the slide is a roller E that follows the form of a shape-plate F , called a rosette. The tool therefore produces a figure that is the exact counterpart of the rosette, provided the tool be on the same side of the centre of motion as the roller; but if the tool be traversed by the slide to the opposite side to the centre of motion, the figure produced becomes an inverted copy, as to the form of the rosette; and these direct and inverted copies are subject to various other modifications, according to the adjustment of the instrument.

Two modifications of the same rosette are shown in fig. 157 and in fig. 158—direct and inverted copies of five rosettes. Every rosette admits of various modifications, and each of these may be combined in various arrangements, as will be readily understood on reference to the circular and elliptical combinations shown in previous figures.

It will be observed that the preceding illustrations of ornamental turning have reference exclusively to patterns produced by the cutting-frames, in the application of which the work remains stationary while motion is given to the cutting tool. The same results might have been illustrated by the converse method of giving motion to the work while the tool remained stationary; thus, the eccentric and elliptic patterns may also be produced by various combinations of the excentric

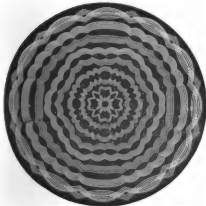
and oval chucks, the choice of apparatus being influenced principally by questions of simplicity of arrangement, and rapidity of execution. This class of excentric and elliptical patterns may also be produced by Ibbetson's geometric chuck, exhibited by Holtzapffel & Co., and which is capable

revolve upon an arbor, but when in action is held by a detent mounted on the lathe-head. The consequence is that when the central wheel at the back is held by the detent, and the chuck is put in revolution, a relative motion is communicated to the front central wheel carrying

FIG. 187.



FIG. 188.



ROSETTES (two modifications), by the Rose Cutting-Frame.

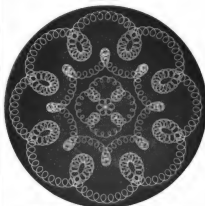
of producing, in addition to those illustrated, a variety of other curves of a highly ornamental character, which may be briefly adverted to.

10. *Ibbetson's Geometric Chuck*.—This chuck consists of two parts. The first part alone gives a simple epicycloidal motion; the two parts combined, a compound epicycloidal motion. In the first part the work is fixed on a wheel revolving on an axis within a slide, mounted on the chuck; motion is communicated to this wheel by a train of wheels, terminating in a central wheel at the back of the chuck, which is free to

FIG. 189.



FIG. 60



PATTERNS produced by Ibbetson's Geometric Chuck.

the work. The amount of this relative motion will depend upon the proportion of the intermediate wheels; thus, supposing the train of wheels to be in the proportion of 3 to 1, a figure of three loops will be traced upon the work by a tool fixed in the sliding rest. If the train of wheels is in the proportion of 15 to 1, a figure of fifteen loops, and so on up to about 250 loops. These loops may be either internal or external, and of any proportion, according to the amount of eccentricity given to the chucks.

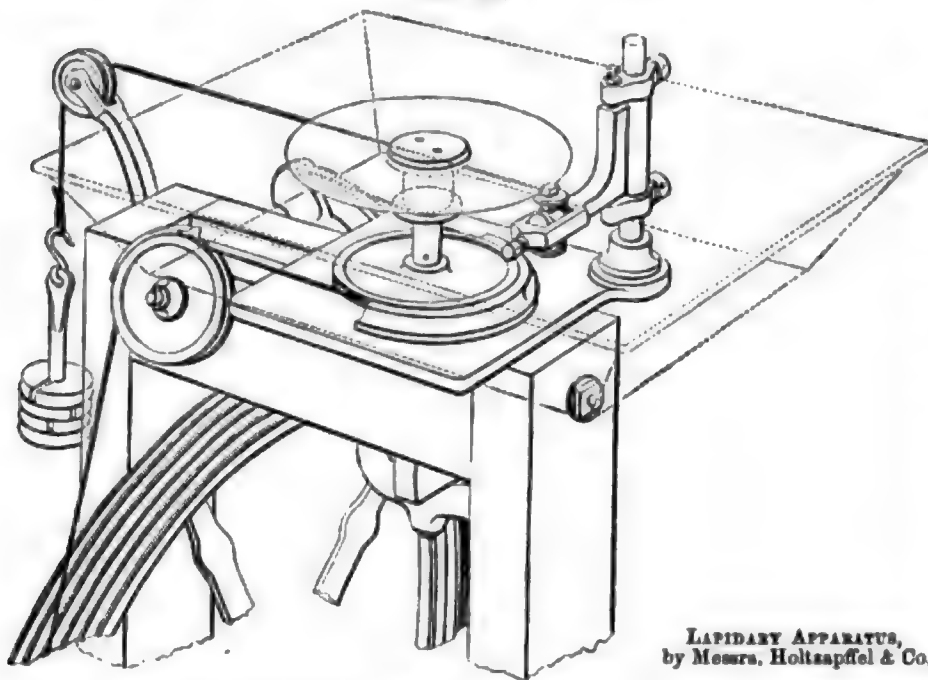
The action of the first part of the chuck is illustrated by fig. 159. The outer pattern consists

of three lines of thirty-two loops outwards; the second pattern consists of four lines of four loops each inwards, the third pattern has three lines of four loops outwards, and the star-like pattern in the centre is composed of a series of ten ellipses, of which the transverse diameters are so small as to cause the ellipses to appear as nearly straight lines.

The second part of the chuck has very similar powers to the first, from which its motion is derived, and the result is that a series of loops may be placed upon each of the primary loops given by the first part; and the numbers and proportions of both may be varied at pleasure, producing practically an inexhaustible variety of epicycloidal lines. The combined action of the first and second parts of the chuck is illustrated by fig. 160. The outer pattern consists of a figure of 192 loops inward upon a primary curve of eight loops outwards. The second pattern has 128 loops outwards upon a curve of eight loops outwards; the third pattern sixty-four loops inwards upon four loops inwards, and the small central pattern consists of six loops outwards, intersecting in the centre. All of the patterns consist of a single line, and the mandril of the lathe revolves once for every loop. Thus, in the outer line the pattern was completed when the mandril had made 128 revolutions, and the central pattern was completed by six revolutions.

11. *Circular Saw*.—Driven by a foot-wheel, has the platform hinged at the back to a casting that receives also the centre screws for the saw-spindle, and an elevating screw in front that determines the projection of the saw, with parallel guide in form of an L square, and a protractor sliding in a groove for cutting angular pieces.

FIG. 161.



12. *Lapidary Apparatus*.—This apparatus is driven by a treadle instead of a winch-handle

as usual, and has the grinding wheels mounted much in the ordinary manner on a vertical spindle. In slicing the stone, it is cemented in a shallow cup supported in a ball and socket joint upon a swing arm that may be fixed at any height relatively to the slicer, the thin end of which is charged with diamond powder, and the stone is pressed against the slicer by an adjustable weight, as shown in fig. 161, which represents the upper part of this apparatus as arranged for slicing. In cutting facets, the stone is cemented in a cup mounted on a goniostat with graduated arcs, by which the stone may be placed in the required vertical and horizontal angles. This instrument has also a divided circle for arranging the number of facets required around the stone. The two feet of the goniostat rest on a platform, and the stone rests upon the cutting wheel; the three points of bearing give a steady position to the whole, exactly as in the drop used in diamond cutting, the two processes being analogous.

13. *Portable Smith's Press-Drill*.—This tool, with a vice-stand, is arranged on a tripod with a standard fitted with rack and slide, upon which is mounted a crosshead, with slide and pressure-screw at the end. The standard may be fixed in any angular position, and the work may be drilled either in the vice on the surface of the tripod or on the floor. This press-drill is applicable to most works below four feet square.

14. *Measuring Instruments*.—Comprising straight edges, squares of various forms, bevils, callipers plain and proportional, with fixed and sliding centres; external and internal sector gauges, marking, sliding, and other gauges, with verniers to read up to one-thousandth of an inch.

15. *Mathematical Instruments*.—Drawing and other mathematical instruments, including in addition those of ordinary construction, Clement's instrument for describing ellipses, in which the pen is placed below the tram-mel movement, to extend its range down to very small ellipses. The tram-mel has screw adjustments, and is mounted upon a hinged frame, sliding on a bar with scale and vernier, and the frame is mounted upon a circular graduated plate, which is moved by a pinion. By this arrangement, ellipses of all proportions, from

the right line to the circle, may be delineated at any required angle to each other, and either con-

LAPIDARY APPARATUS,
by Messrs. Holtzapffel & Co.

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curves and scales, from its economy, flexibility, and identity of contraction and expansion with drawing paper.

17. *Printing Presses.*—Printing-presses for amateur use, on the principle introduced by the late Professor Cowper, in which the platten and the tympan are combined in the same piece, hinged at one end, and the pressure is applied at the opposite extremity by a modification of the knee or toggle joint. Simplicity and economy of construction are the recommendations of this principle, but its advantages are limited to sizes not exceeding broadside foolscap.

18. *Miscellaneous.*—Among other miscellaneous tools were exhibited mineralogical hammers of various forms, cutter-bars with detached blades for turning and planing, hand-planes for thin sheet-metal, screw-wrenches, and other hand-tools.

CHAPTER XIX.

MACHINE-TOOLS EXHIBITED BY MESSRS.
A. SHANKS AND CO., LONDON.

Messrs. Shanks & Co. exhibited a number of tools, which were remarkable for their originality, simplicity, and efficiency, combining cheapness with good and rapid performance.

1. *Duplex Mortising and Grooving Drilling Machine.*—This is a double-acting slot-drilling machine in which the principal novelty consists in the employment of two drills working simultaneously. The drills enter the work horizontally from two opposite sides, and approach each other until they meet in the middle of the work. The drill-spindles are driven direct by cone-pulleys, and the headstocks carrying these pulleys slide transversely on a carriage which is traversed on a horizontal bed. The traversing motion is derived from a stud in a revolving disc, and is equalized by means of a pair of elliptical spur wheels. The feed-motion is obtained at each end of the traverse by causing the two headstocks and drills to approach each other by means of a right and left hand screw worked by a ratchet-wheel. The drills are prevented from touching each other by means of a stop-nut, to stop the feed at the right point. One drill being then withdrawn, the slot is finished by the other (fig. 162, page 191).

To cut mortises with one end bevelled to suit the taper of the keys, an oscillating table with a combined slot movement is used.

As the two cutters work in opposition to each other, they hold the work steadily between them, and as they each penetrate to but half the depth of the slot they are made shorter and stiffer than single-acting drills can be made, which cut

the whole depth. The advantage of the additional stiffness so acquired by the drills is apparent in their accurate and finished execution, which is completed at one operation, without the aid of a rosebit.

2. *Friction-gear Drilling Machine.*—This is a neat and convenient machine, carrying four spindles, with drills of different sizes, in a revolving frame. They are driven by Robertson's friction-gear from a central friction-wheel on the main spindle, which is upright. The frame turns on a bearing slightly eccentric to the main spindle, so that each drill is brought into gear when over the table, and disengaged or placed out of contact when turned aside.

FIG. 163.



Friction-gear Drilling Machine, by Messrs. A. Shanks & Co.

The friction-pinions on the respective drill-spindles are proportional to the sizes of the drills, to give each drill its proper speed. This system of friction-driving is suited for high velocities and little resistance (fig. 163).

3. *Multiple Drilling Machine.*—This machine, of which a model was exhibited, is designed for drilling at one operation the tube-plates of locomotive boilers, or other work where a number of holes of the same diameter are to be drilled. The drills are turned by means of a crank on the upper end of each, connected to a plate which



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upon the shank of the hammer, and is regulated by suitably compressing or wedging the spring. The degrees of coarseness and fineness of the teeth are obtained by means of ratchet-wheels. These machines are specially adapted for making files of 10 inches in length, and upwards, suitable for engineers' use. The files are also forged by machinery.

Mr. J. Glasgow, Manchester, exhibited a *screwing machine*, for $\frac{1}{4}$ -inch to 2-inch bolts. The bolt is held by a chuck on the spindle, and revolves; the dies are set by means of an index-wheel, and are stationary in a frame, which is traversed on two slide-rods. The spindle is hollow, and is driven from a four-speed cone, with intermediate gearing. It has a reversing motion of three mitre wheels and double clutch. This machine is heavy to work, there is no appliance for shifting the die-frame, and there are no fewer than seven toothed wheels for driving it.

Messrs. William Gadd & Son, Nottingham, exhibited a *screwing machine* of equal merit with the one just described. The spindle is telescopic, in two sections, of which the inner spindle is fitted at one end to receive the chuck for holding the bolt to be screwed; and the other end receives and retains a guide-screw of the required pitch of the bolt to be screwed, and working through a nut carried in a bracket fixed to the headstock. The driving-gear is fixed upon the hollow or outer portion of the spindle, and consists of a pair of single friction-cone pulleys, driven by belts in contrary directions, between which a double cone is moved by clutch action, into gear with the one or the other for a forward or a return motion. Thus the guide-screw prevents false starts or the cutting of bad threads. The dies are adjustable vertically in a frame, and are not fixed, but loaded with a weighted lever to give a uniform cutting pressure. A stop or gag is placed between the dies to fix the gauge and define the size of the screw. Bolts are usually run through three times to complete the screw.

Messrs. G. & A. Harvey, Glasgow, exhibited a selection of plain, solid, and substantial tools. They showed an 11-inch *lathe*, with conical bearings for the cone-spindle; second, a *shaping machine*, with four spur-wheels, to connect the motion for driving the ram, which are too many. The ram is driven with a connection at one side; for the feed-motions, eight spur-wheels are employed. Third, a *planing machine*, with a table 8 feet long, driven by a double or stepped rack of unusually large size—6 $\frac{1}{4}$ inches

broad, with teeth of 1 $\frac{1}{2}$ -inch pitch. Fourth, a *radial drill*, of ordinary construction.

Messrs. D. Cook & Co., Glasgow, exhibited a *steam riveting machine*. The heading die acts horizontally, and is moved by an eccentric on a rocking shaft, which is acted on by steam-pressure on a trunk or plunger in a single-acting cylinder, connected to the end of a lever on the shaft. The cylinder is vertical, and let into the floor out of the way. Steam is admitted to the under-side of the piston, and the valve is worked by hand, and timed to suit the work, in order that no time should be lost, nor work spoiled by missing stroke. The momentum of the moving masses assists in riveting. The machine can close at an average rate ten to twelve rivets per minute in plain work. The most rapid performance gave twenty rivets per minute, every preparation having been made. The machine can actually be worked at sixty

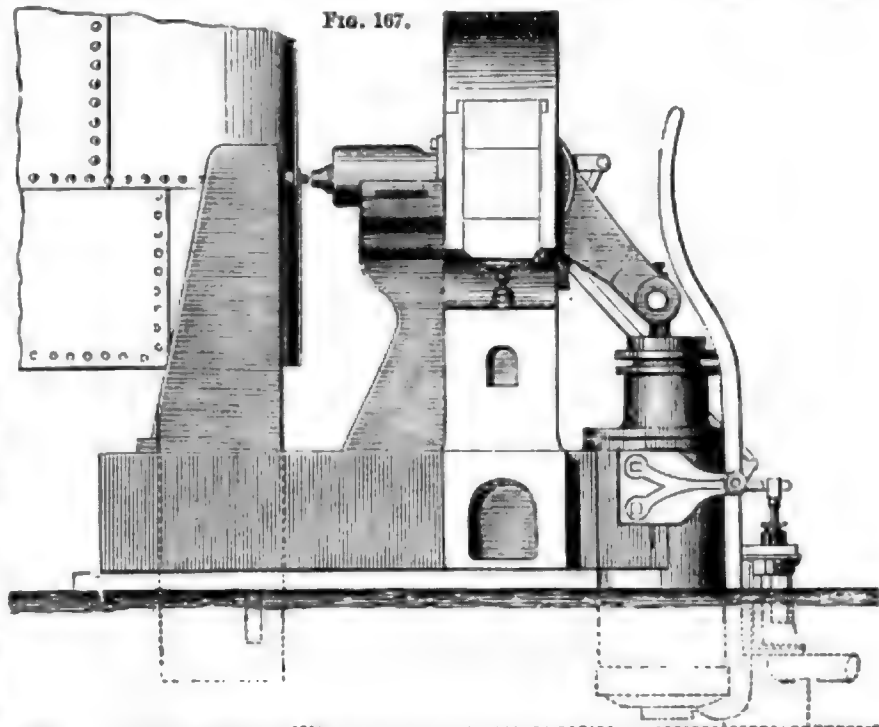


FIG. 167.
STEAM RIVETING MACHINE, by Messrs. D. Cook & Co., Glasgow.

strokes per minute. The plunger is 7 inches in diameter, and, with a 26-inch lever, $\frac{3}{4}$ -inch riveting can be done with 25 lb. steam. With a stroke of 2 feet the riveting die traverses a space of 3 $\frac{1}{2}$ inches. The machine is capable of closing 1 $\frac{1}{4}$ -inch rivets (fig. 167).

Messrs. Cook & Co. also exhibited drawings of *punching and shearing machines*, constructed on the same principle of action, combining the three functions of punching, shearing, and riveting in one machine. The usual size of the cylinder is 15 inches diameter, 30 inches stroke, with a 2-foot lever, having 3 $\frac{1}{2}$ inches motion of the die for riveting, and 1 $\frac{1}{2}$ inches motion for punching and shearing. With 18-inch cylinders, and steam of 40 lb. per inch, 1 $\frac{1}{4}$ -inch holes are easily punched through 1 $\frac{1}{4}$ -inch plates.

Messrs. Crawhall & Campbell, Glasgow, exhibited a *horizontal boring machine* for boring

cylinders up to 4 feet in diameter, and $5\frac{1}{2}$ feet long. The sole-plate is 15 feet long,—the whole length of the machine. At one end, the principal frame is erected, consisting of two standards and a lintel, like those of a planing machine; on the face of the standards, the boring-bar carriage may be adjusted to the proper height by means of a pair of screws worked within the standards, by hand or power, the face of the frame being graduated to show the elevation of the bar. The driving-gear is carried on the top:—from a five-speed cone, with back gear, the power is transmitted by an upright shaft to a horizontal shaft on the back of the boring-bar carriage, from which it is transmitted by spur-wheels to the boring-bar. The boring bar is, in fact, encased by and slides within a hollow spindle, which has its bearings on the carriage, and receives the power by the spur-wheels. Two feathers on the bar slide in grooves in the sheath, and so the bar turns with the sheath. An extra bar, of suitable length, for carrying the cutters, is cottered to the socket-bar, the other end being carried in a bearing on the sole-plate. The feed is given by means of a differential-motion from the sheath, and a screw bearing on the end of the bar. The toothed gearing of this machine is not in proportion:—the fast and slow gearing for driving is all of one pitch and width of teeth; the spurs which turn the spindle sheath, itself 6 inches in diameter, are only 13 inches in diameter, with teeth only $3\frac{1}{4}$ inches broad, and only $1\frac{1}{4}$ -inch pitch.

Messrs. J. Hunt & Co., Bow, exhibited a *bevil-wheel cutting machine*, simple in design and construction, and perfectly efficient for the purpose. It is, essentially, a shaping machine, with a reciprocating cutter. The block-wheel to be cut is presented to it in front, fixed on a spindle at the proper inclination, with a dividing disc on the upper end for pitching the teeth. The spindle is carried in swivel bearings, and has two motions, one for pitching the teeth to be cut, by turning on its own axis; the other for setting it to the proper inclination of the teeth to be cut. By means of holes in the dividing disc, and an adjustable pointer, the pitching is accurately performed; and the vertical feed for cutting to the bottom of the spaces and forming the teeth is obtained by a cam and ratchet motion from the driving-shaft, which, by means of a worm and segment on the horizontal swivel bearing, raises the block-wheel to the cutter. The cutting of the tooth to the proper form is done by the aid of a template which acts on a straight edge in a line with the cutter. The vertical-feed movement is thrown out of gear, when the bottom of the tooth is reached, by means of a spring detent. The cutter shapes only one side of the tooth at a time; and after having travelled round the circumference of the wheel, forming one side of each tooth, it is replaced by another cutter to complete the remain-

ing sides of the teeth. It is stated that the machine is capable of pitching and trimming as many wheels in one day as can be done by a good workman in a week.

Mr. Wm. Ryder, Bolton, exhibited a *forging machine*, to forge, draw, or swage small articles in iron or steel, up to 2 inches diameter, or 2 inches square,—rollers, for example, spindles, bolts, studs, files, shaft ends. The machine contains four pairs of dies in a row, successively for cutting, for square forging, for round forging, and for flat forging or forging shoulders. The lower dies or anvils have a slight elastic bearing, and are adjusted by screws to the required elevation. The upper dies are fixed in the ends of four plungers, $4\frac{1}{2}$ inches diameter, carried in two slides, and they derive their motion from eccentrics on a shaft above, each eccentric being between two bearings. The eccentrics work "pushers" down upon the plungers with ball-and-socket contact; and the plungers are raised by springs which retain them in contact with the pushers. The plungers make a stroke of half an inch, and make 750 strokes per minute. The machine is very efficient, and is very much used in forging the top rollers, flyers, and other light parts of spinning machinery. It is unsuited for objects more than 2 inches thick; if larger they are likely to be spongy. Second, a *fluting machine*, for fluting rollers with parallel or diagonal flutes, for cotton or other machinery. In this machine, ten rollers may be fluted at once, for which ten cutters are placed in a row on a stationary frame. The work is traversed under the cutters by the application of a worm-wheel and slotted-link motion, applied as in a shaping machine, with a quick return. Weild's appliance for cutting a wavy or serpentine groove on the surface of the roller is fitted to the machine, having a wavy template, from which a reciprocating motion is transmitted to the cutter-frame at right-angles to the rollers passing under the cutters. The pitch or separation of the cutters is adjustable. A self-acting ratchet-feed motion is applied to turn each of the rollers.

A fluting machine has recently been invented by Mr. Weild. It operates by indenting or compressing the surface of the roller into flutes by means of dies.

Messrs. Richard Roberts & Co., London, exhibited drawings of the *multifarious* or *Jacquard punching machine*, invented by Mr. Richard Roberts, and used by Messrs. Peto & Co., at the Canada Works, Birkenhead, designed chiefly to facilitate and economize the construction of wrought-iron bridge-work. The plates, especially those in the top and bottom flanges of such structures, are pierced with numerous rivet-holes at a regular pitch; but there are also interspersed holes for securing T iron and angle iron, transverse roadway girders, &c. The object of the manufacturer is to arrange the plates so that the series may consist of a repetition

of one punched pattern as much as possible, and in that case one or two "templates" will suffice for marking off the place of the rivet-holes in each plate. The construction of these templates, however, and the subsequent marking and handling of each plate, adds considerably to the expense, and various efforts have been made to abbreviate these operations. Among the most conspicuous is the Jacquard machine, in which the pattern of plate is arranged on a number of Jacquard cards, which, combined with suitable mechanism, throw a certain number of transverse punches out, and bring others into gear at each stroke of the machine. The plate is advanced the proper distance by self-acting machinery before each stroke of the punches, and in this way the pattern is reproduced in each plate with great quickness and precision. This Jacquard machine was successfully used in the construction of the Conway bridge, the Boyne viaduct, the Victoria bridge at Montreal, and subsequently for preparing the plates in many other large bridges. As there are necessarily a good many parts in this machine requiring adjustment, Messrs. Peto & Co. state that they do not use it unless they have a bridge of several hundred tons weight in hand; but it has stood the test of twelve years' work, and remains in good condition.

Messrs. Peto, Brassey, & Betts, Birkenhead, exhibited models of *machines for manifold drilling and multifarious punching*, designed with the object of superseding the Jacquard punch, but only as yet constructed in model:—

"1. *Multifarious Punching Machine*.—This machine is considered by the exhibitors to be a decided improvement. It is, as compared with the Jacquard, so simple that it can be managed by an ordinary machine-man; whereas the Jacquard requires the constant attention of an experienced mechanic. It has been noted that in each series of punched plates the same punches are frequently employed time after time at each stroke; and that there is, in fact, no necessity for the endless number of variations which can be afforded by the adoption of the Jacquard principle. Accordingly the new machine is made to give twelve variations in transverse punching on each plate operated upon; and the exhibitors believe that this will be found amply sufficient in practice. The main features of the contrivance are two rotating drums, which revolve one-twelfth part of a complete revolution between every two strokes. The dies are fastened on the lower drum, which is hollow, for the reception and removal of the pieces punched out, and the steel punches on the upper drum. When the transverse holes have to be repeated, the drum can remain stationary during the progress of the plate, but when a new set of transverse holes are required, the self-acting apparatus at the side of the framing rotates the drum so as to bring a fresh set of dies and punches into

play. The upper drum is moved vertically in the ordinary manner by excentrics turned on the upper main shaft, and makes about sixteen strokes per minute. The machine has space on the drum for thirteen punches, and can therefore punch thirteen holes through $\frac{1}{2}$ -inch plate, each $1\frac{1}{8}$ inch diameter, at each stroke, or over 200 holes per minute, if required.

"No preparation of templates or marking of the plates is requisite, as the self-acting mechanism rotates the drum for differences in transverse pitch, and advances the plate to the proper extent for longitudinal pitch at each stroke; and there is this advantage, that both *curved work* and *variations of longitudinal pitch* can be performed by this machine, which could not be managed by the Jacquard apparatus without great extra complexity. In large bridges, where heavy plates pierced with a number of rivet-holes are required, the use of such machinery effects a great saving in the expense of manipulation, and in the time required for completion of the work.

"2. *Simultaneous Manifold Drilling Machine*.

—The object of this machine is to effect an economy of labour with drilled plates similar to that derivable from the punching machine above explained, when the work has to be punched merely. The greater attention which has been paid during the last few years to the details of iron structures and to their more complete finish, has gradually led to the use of drilled instead of punched holes in many important works. Not only is it imagined that greater accuracy in the position of the holes is obtained by the use of the drilling-apparatus, but also that the strength of the iron remaining between the holes is considerably greater than when punching is employed. There can be no doubt that in any case, but more especially with badly-formed punches and dies, a great, and perhaps an excessive strain may be thrown upon the intermediate iron in forcing the punches. This idea is at least gaining ground, and it is not uncommon to find that drilled holes are specified in bridge-plates, or in boiler-plates, which have to withstand a considerable strain. When, to the evil of weakened material, is added the injury that may accrue from 'drifting' badly-punched holes, there seems reason to believe that the use of the drilling machine would, in many instances, improve a great deal of our iron-work. The model of the drilling machine exhibited represents a machine intended to operate upon bridge-plates, specially to get over a number of holes at one time. It is considered that by thus completing the plate at one operation the cost of the drilled holes may be less than when formed one after the other at the ordinary punching press. It is, of course, much more expensive to drill hole after hole than to punch them; but, by the use of the compound drilling machine, one setting of the plate is sufficient, and the work is finished in little more

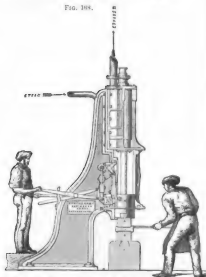
than the time requisite to bore one hole in the ordinary manner. It is believed that the machine exhibited by model is superior to any other compound drilling apparatus yet constructed, or even proposed. Its superiority lies in the facility with which the position of the drills can be altered, either longitudinally or transversely, for different patterns of plates. In other machines which have been made and proposed for a similar purpose, the drills run in holes cast in a frame, and are incapable, therefore, of any variation of pitch. To drill a new pattern with such machine requires the removal of the frame and substitution of another with the holes properly arranged, which is both expensive and troublesome if many different patterns are required. In the model exhibited, the pitch can be varied both transversely and longitudinally without disturbing the drills and framework.¹

CHAPTER XXI.

STEAM-HAMMERS.

Several steam-hammers not associated with other machines, were exhibited, and they are here, for convenience, described in one chapter.

FIG. 189.



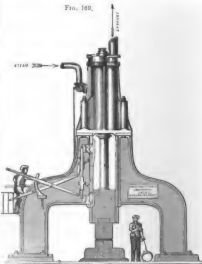
NAYLOR'S STEAM-HAMMER, by the Kirkstall Forge Company.

1. The Kirkstall Forge Company, Leeds, exhibited one of Naylor's 4-cwt. hammers, together with a model of one of his larger hammers. The original feature of this hammer consists in its double action, the steam being admitted above

as well as below the piston, to accelerate its fall, and increase the force of the blow. This hammer may be made single-acting or double-acting, by regulating the valves; the supply of steam, and the height of fall, and force of blow, may also be regulated by the gearing. Steam is admitted throughout the whole of the stroke; and the variation in the force and the rapidity of the blow is effected by wiredrawing the steam more or less. The gearing is made with two slide-surfaces, acted on by a roller attached to the hammer-block, from the movements of which the valves are opened and closed for the admission and exhaustion of the steam. The slides are raised or lowered by hand, to fix the points of the stroke at which the steam is admitted above or below the piston, and the height and depth of the rise and fall. The connection of the slides is such that they may be shifted vertically, independently of each other; they have also a limited horizontal traverse for adjustment, and in this sense they are linked, and they slide together. An air-valve is applied at the upper end of the cylinder, to admit air to follow the piston, and prevent a vacuum, when single-acting, and to act as an elastic cushion to accelerate the descent of the hammer (figs. 168, 169).

2. Messrs. Robert Morrison & Co., Newcastle-on-Tyne, exhibited a 20-cwt. double-acting steam-hammer. The frame is made with a front and

FIG. 190.



NAYLOR'S LARGE STEAM-HAMMER, by the Kirkstall Forge Company.

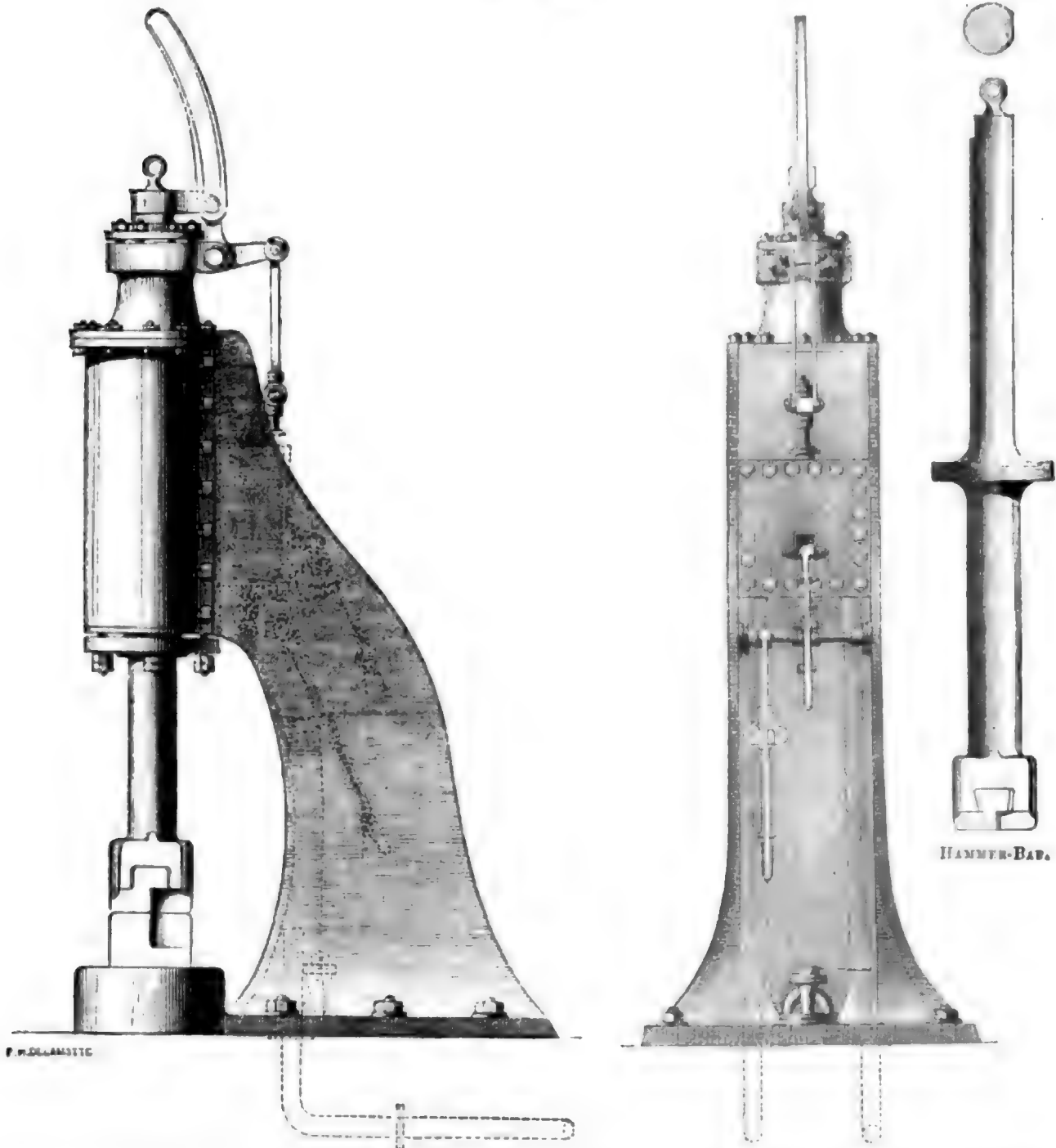
two sides, like the letter **E**, in horizontal section, and contains the gearing at the back, between the sides, with the steam and exhaust passages cast into the angles. The hammer-bar and the

piston are forged together in one piece, the bar being extended above the piston and passed through the top of the cylinder, with two stuffing-box guides above and below. The piston is made steam-tight by two small steel rings, and the bar above the piston is planed flat on one side, passing through a corresponding stuffing-box and gland, to act as a guide for keeping the

hammer-face square with the anvil. The ordinary valve is worked from a crosshead on the upper end of the hammer-bar by means of a curved slotted link; and the variation of the stroke, and the force of the blow, are made by means of a movable gridiron face-plate, interposed between the valve and the face of the cylinder, and adjustable by hand (figs. 170, 171).

FIGS. 170.

FIG. 171.



20-CWT. STEAM-HAMMER, by Messrs. Robert Morrison & Co., Newcastle-on-Tyne (showing the Hammer-Bar and Piston separately).

3. Messrs. Hudswell & Clark, Leeds, exhibited a 4-cwt. hammer, double-acting. It has a double conical valve applied at the back of the cylinder, for which a self-acting motion is derived from the tup by a lever, the end of which is linked to it. The valve is double, cutting off the steam close to the cylinder at each end. By shifting the

steam-handle to three several positions, the hammer is made respectively single-acting, or with half steam admitted also on the top of the piston, or with full steam on the top. The piston and rod are forged in one piece, and the lower end of the rod in the tup is enlarged to prevent its being spread by hammering. The

standards are open behind to admit of long work being placed on the anvil in various directions (fig. 172).

FIG. 172.



4-CWT. STEAM HAMMER,
by Messrs. Huddell & Clark, Leeds.

4. Messrs. Thwaites & Carbutt, Bradford, exhibited a 7-cwt. self-acting double-action hammer, in which the self-action was produced by the action of three cams or inclined planes at different elevations, on the back and on the front of the hammer, upon rollers connected at the one side, for admitting the steam under the piston, and at the other side for cutting it off and exhausting it; and so regulating the height and depth of the stroke, by setting each roller to one or other of the cams. The admission of steam

FIG. 173.



4-CWT. STEAM HAMMER,
by Messrs. Thwaites & Carbutt, Bradford.

above the piston is regulated by hand; the steam is not exhausted, but remains as a cushion, to increase the velocity and force of the blow.

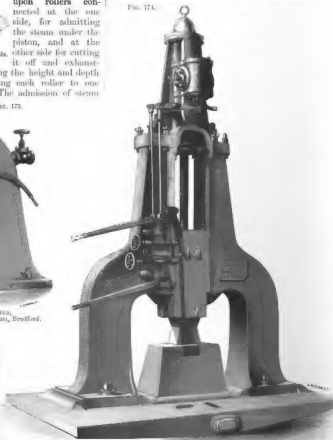
A 4-cwt. hammer also was exhibited for smith work. It is double-acting, worked by hand, and self-contained, — in one casting (fig. 173).

The exhibitors have, since exhibiting these hammers, modified the details of the larger hammer, by substituting for the cam-motion from

the top, the movement of a bowl working in an inclined groove cut in the face of the tup, which, when the tup rises, acts upon a tappet-frame, with two tappets adjustable by screws, to act upon the valve, and vary the force and extent of the blow. The hammer may also be worked by hand (fig. 174).

5. Mr. J. Rhodes, Wakefield, exhibited a steam-hammer, in which the valve-gear is worked by a tappet on the hammer-head, to which is presented a forked lever, spread in the form of a circular segment, the upper and lower ends of which are tapped alternately, according to the rise and fall of the hammer. The stroke is shortened by shifting the fulcrum

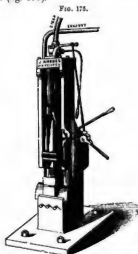
FIG. 174.



STEAM-HAMMER, by Messrs. Thwaites & Carbutt. (New Design.)

of the lever nearer to the tappet, thus causing the lever to be struck, and the gearing to be reversed,

within a shorter range of the hammer. According to this contrivance, the stroke can only be shortened by reducing it at both ends, as the piston must work to and from the middle of the cylinder (fig. 175).



STEAM-HAMMER, by Mr. J. Rhodes, Wakefield.

6. Messrs. Glen & Ross, Glasgow, exhibited two of Rigby's steam-hammers, of $2\frac{1}{2}$ cwt. and



RIGBY'S STEAM-HAMMER, by Messrs. Glen & Ross, Glasgow.

6 cwt., and a drawing of a 6-ton hammer on the same principle. The $2\frac{1}{2}$ -cwt. hammer has a

9-inch cylinder, and a fall of 20 inches. The 6-cwt. hammer has a 12-inch cylinder, and a 2-foot stroke. The piston and rod are forged in one piece, and the piston-rod is flattened on two sides, working through corresponding glands, which act as guides. The valve is cylindrical, and balanced, consisting of three discs within a cylinder, forged at intervals on a sliding spindle, between which the steam is admitted and distributed. The steam admitted below the piston is afterwards exhausted to the upper sides, and follows the piston in the descent. Thus an excess of pressure is obtained on the upper side for double action, measured by the sectional area of the piston-rod. A saving of steam results from this arrangement, compared with an ordinary single-acting hammer, particularly in forging deep masses (fig. 176).

Messrs. J. Eastwood & Sons, Derby, exhibited a small self-acting double-acting steam-hammer, or steam-tilt, for tilting cast-steel. A revolving steam-valve is reciprocated by a link which works in an inclined slot on the front of the tup. It is a simple machine, suited for giving quick blows,—350 to 400 per minute. The lift can only be varied by changing the speed, lifting higher as it goes faster, with more steam. The blow is not heavy when it descends upon a thin object on the anvil, as the steam for the ascent gets below the piston before the stroke is completed.

7. Messrs. Carrett, Marshall, & Co., Leeds, exhibited Joy's self-acting steam-hammer. The peculiar feature of this hammer is the floating piston-valve for the distribution of the steam to the cylinder. It is moved up and down by steam admitted from the cylinder, alternately from the upper and lower sides of the hammer-piston, by small openings through the side of the cylinder, covered and uncovered alternately by the piston in its ascent and descent. The steam admitted during the ascent of the piston raises the valve, which shuts off the supply to the cylinder, and thus terminates the up-stroke. For the purpose of regulating the height of the lift, the steam is admitted to the valve through one or more of a series of holes in a vertical row in the side of the cylinder; and the lower the opening is made for the escape of the steam to the piston-valve, which is adjustable by a slide moved by hand, the sooner the supply is shut off to the lower end of the cylinder, and opened to the upper end, and the shorter the stroke. Again, the steam admitted to the valve from the upper end of the cylinder, pressing it down, shuts off the supply above, and opens for steam below the piston; and by wire-drawing the steam so admitted above, the descent of the valve may be regulated to time the opening for steam below, after the piston strikes the blow, until which time the hammer-bar holds to the anvil like a vice (figs. 177, 178).

By closing the openings to the valve from the cylinder, the hammer may be worked by



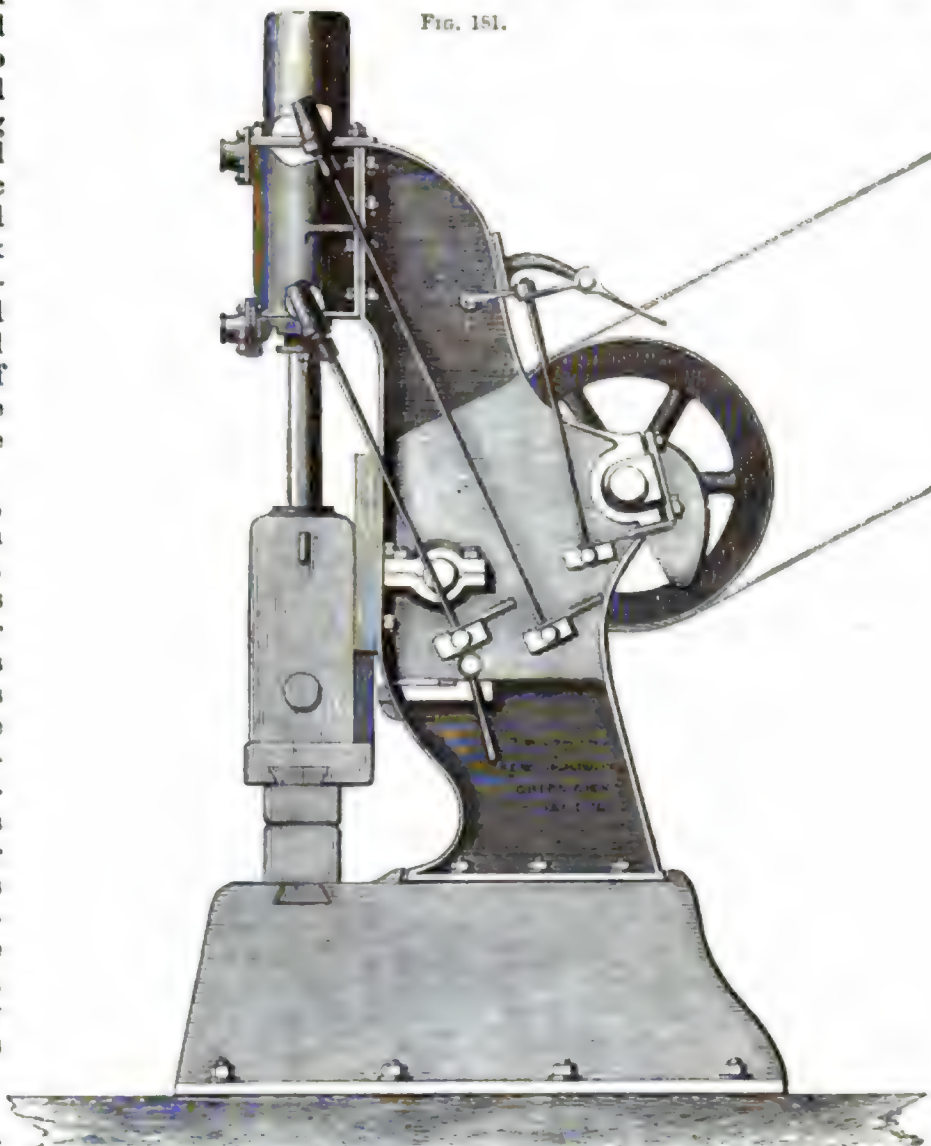
9. Mr. John Imray, London, exhibited Imray & Copeland's hammer, with a "hydraulic anvil and striker." The hammer is fitted to the end of the piston-rod with an intervening liquid "cushion" (?) of oil to diffuse the pressure and save the rod from being upset. The anvil is mounted on the ram of a hydraulic cylinder, of which the level may be varied. The shock is described as being "transmitted to the framing and foundation through a liquid cushion, which takes off the whole violence of the concussion." This may be questioned.

10. Mr. T. W. Cowan, Greenwich, exhibited an "air-compressed" hammer. The ordinary piston works in a cylinder full of air with cocks at both ends for regulating the ingress and egress of the air. The motion for lifting the hammer is derived from a cam-shaft. When all the cocks are fully open, the hammer rises and falls freely by its own gravity; but by partially or wholly closing one or both of the air-cocks, the force of the blow may be increased or reduced as required (fig. 181).

Note.—The steam-hammers exhibited by Messrs. Nasmyth & Co., and by Mr. Hulse, are noticed with their other machines at pages 163 and 149.

made from the best cold blast iron, and are finished by boring out the inner surface similarly to the cylinder of a steam-engine, and when

FIG. 181.



AIR-COMPRESSED HAMMER, by Mr. T. W. Cowan, Greenwich.

finished the surface must be free from pin-holes or other defects. The duration of these "chills" is very various. Sometimes they will crack in casting the first or the second roll, and the expense of frequent renewals of chills forms a large item in the cost of the rolls.

The method of casting is as follows:—The necks and "wabblers" forming the ends of the rolls, are moulded in sand contained in iron boxes or flasks, in the usual manner, and the iron mould or "chill," which forms the matrix, or mould for the body of the roll, is placed between the boxes which contain the necks. The entire mould is fixed on end, and the melted iron poured into it. When the molten iron comes in contact with the surface of the iron mould it is suddenly chilled to a greater or less depth, and assumes a peculiar crystalline texture, which when broken shows a silvery fracture. The depth or amount of "chill" on the surface of a roll does not depend upon the time it remains in the mould, but is of instantaneous formation

CHAPTER XXII.

METAL ROLLS, ETC.

Rolls are made of various diameters, from 6 inches to 24 inches, and the depth of the case-hardened surface, or chill, is varied to suit the work to be rolled. For rolling hot sheets of metal the depth of chill averages $\frac{3}{4}$ inch in depth, and for rolling cold sheets the chill is from $1\frac{1}{4}$ to $1\frac{1}{2}$ inch deep. The rolls are cast in iron moulds, technically termed in England "chills," and in France "coquilles." The moulds vary in thickness according to the size of the rolls, and are from 12 to 18 inches thick. They are

at the moment the melted iron touches the iron mould.

The trade of chilled-roll casting is one peculiarly liable to heavy losses from wasters. A few pin-holes in the surface, or a too great or too little depth of the case-hardened surface, necessitates their rejection; and such defects are frequently only discovered after considerable labour has been expended upon them in turning.

The great desideratum in chilled rolls is to combine a uniformly hard and homogeneous surface with great strength. It is found in practice that "cold blast" pig iron alone has the property of acquiring the necessary hardness of surface when run in contact with iron moulds; and even in a make of iron suitable for the purpose it is only a certain class of pigs, possessing a peculiar crystalline arrangement of particles, that can be used. These pigs are selected a few at a time out of every "cast" or "running" at the blast furnaces; and this is an operation which requires a very practised eye, success in which can only be acquired after many years' experience.

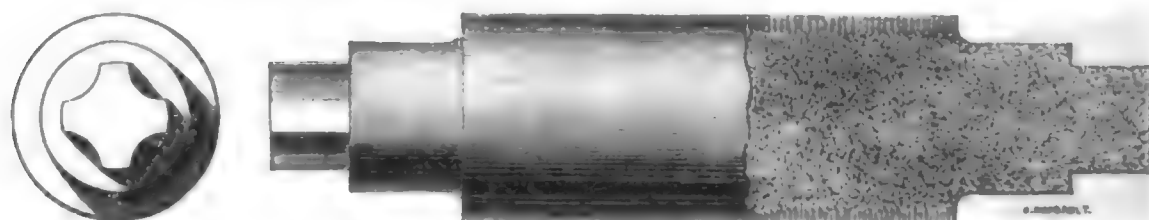
The iron which possesses the greatest degree of hardness when chilled is frequently deficient in strength, when it requires to be mixed with other irons of greater strength, so that the mixture may unite the two properties of hardness and strength. But as there is no chemical affinity between one make of iron and another, it is impossible to obtain a perfectly homogeneous and uniform quality of iron from several mixtures by once melting only. Messrs. Perry & Son have for some years adopted the plan of melting their various mixtures together, and running them into pigs, and again re-melting these pigs several times till the required uniformity is obtained; but as this process is attended with very considerable expense, it is obvious that it can only be done in making rolls of first-class quality.

Messrs. Thomas Perry & Son, Highfields, Bilston, exhibited a large *hard-chilled sheet-roll* 21 inches in diameter and 4 feet 4½ inches long in the body, turned and polished for rolling sheet-metals (fig. 182); also a pair of 8-inch chilled guide-rolls, 8 inches long in the body, and turned for rolling round iron.

Messrs. Smith & Hawkes, Birmingham, exhibited a *chilled roll* 22 inches in diameter and 30 inches long in the body. They exhibited also a testing-machine, such as they use to prove the quality of their iron. The iron is prepared in bars one inch square, which are laid upon supports 18 inches apart. The pressure is applied transversely at the centre between the supports, by means of a lever and weights.

Madame Sinibaldi, Greenwich, exhibited Sisco & Sinibaldi's system of *manufacturing chain-cables* from cold-rolled hoop-iron, brazed. The chain is made of hoop-iron of the breadth required; each link is formed by winding the hoop-iron upon a mould which revolves, until the required thickness of link is obtained. When a sufficient number of links are in position, they are plunged in a bath of melted metal, and the whole of the laminæ are bound together. Central studs and end-wearing pieces are then brazed in. The usual test-strain of a 2-inch iron chain for naval service, is 72 tons. One of the hoop-iron chains, 2 inches broad and 2 inches thick, on being tested at Woolwich, broke the 2½-inch testing-chain at 114 tons. A chain of the same size was afterwards tested by a strain of 120 tons. There can be no doubt of the strength of a cable formed in this manner. It is well known that, proportionally to the sectional area, thin rolled iron is stronger than thick iron. The Government is now alive to the necessity for testing chain-cables, from the failures of which numerous losses at sea take place annually. The hoop-iron cable deserves to be fully and fairly tried.

FIG. 182.



SHEET-METAL ROLL, by Messrs. Thomas Perry & Son, Highfields, Bilston; partly in section to show the chill.

CHAPTER XXIII.

FOREIGN MACHINE-TOOLS.

Madame De Coster, Paris, exhibited a *shaping machine* and a *vertical drill* of common construction. The ram of the shaping machine is like Messrs. Muir's, in the form of a thick plate on edge, sliding in V grooves at the upper and lower edges, with the driving-pin on one side.

MM. Varrall, Elwell, & Poulot, Paris, exhibited a *planing machine* to compass 6½ feet by 3 feet, by 3 feet high. It is driven by means of spur-gear, with a double rack and tumbler motion.

MM. J. & C. G. Bolinder, Stockholm, exhibited a *compound planing and shaping machine* suitable for small factories.

M. R. Hartmann, Chemnitz, exhibited a selection of machine-tools. — 1. An 8½-inch *Lathe*,

having a guide-screw for screw-cutting and sliding, with a half-nut eight inches long. A feed for surfacing is obtained from the screw by a worm-wheel on a cross shaft. 2. *A Slotting Machine*, in which the vertical motion for the ram is taken off the side of the spur-wheel. 3. *Nut-cutting Machines*, two in number, one for facing and bevilling the edges of the nut, which is secured upon the end of a revolving spindle, by means of two separate cutters fixed in one slide and acting together. The other machine is for shaping the sides of nuts. It is double-headed, with vertical action like a slotting machine. Each head works a pair of cutters to shape two opposite sides at once. The nuts are fixed on a vertical mandril, with a compressible conical end to tighten in the nut. The feed is horizontal, cutting both ways, and no time is lost in backing. The connection for the feed is elastic, and elongates to save breakage should the slide get jammed. It is stated that 350 nuts $\frac{3}{4}$ -inch diameter, or 500 nuts $\frac{1}{2}$ -inch diameter, may be cut per day. 4. *A Radial Drilling Machine* on a large square cast-iron base, co-extensive with the range of the jib, planed, with a solidly-designed frame, in one casting, carrying within it the driving and driven cones. The jib swivels on a fixed pivot on the upper part of the frame. 5. *A Slot-drilling Machine*, in which the work is traversed under the drill.

M. J. Zimmermann, Chemnitz, exhibited a selection of machine-tools for working in metal and in wood. The machines for metal, comprising with other things a planing machine and a slide-lathe, were constructed on the models of English tools, excepting two nut-cutting machines, single and double-headed, with double cutters, similar in construction to M. Hartmann's. Also a machine for squaring or cutting off the ends of boiler-tubes, and for turning the ends outside and inside, for the purpose of repairing the tubes, by soldering new pieces to replace worn ends.

MM. Sondermann & Stier, Chemnitz, exhibited a tube-cutting machine like that of M. Zimmermann.

Foreign Steam-Hammers. — Messrs. Farcot & Son, Paris, exhibited a species of double-acting steam-hammer, in which the steam plays only above the piston, for the down stroke, and works against a permanent cushion of steam below the piston.

MM. Varrall, Elwell, & Poulot, Paris, exhibited a steam-hammer, constructed on Naylor's principle. The piston-rod is excellently connected to the tup; it is spherically enlarged at the end, and let into a chamber in the tup, and there embraced by conical wedges round the neck to prevent its withdrawal. On the lower side, it is packed with a steel plate, hollowed to fit the spherical end, and wedged up taut through the side of the tup. Thus, with ease, the rod may be disengaged from the tup,

if necessary; whilst, in other hammers where the rod is cotted into the tup in the usual manner, there is frequent difficulty in extracting the rod in consequence of its being staved up.

MM. Schmerber Brothers, Mulhouse, exhibited a hammer, lifted by means of a cam on a revolving shaft, engaging in a vertical slot in the hammer. The shaft is made with india-rubber couplings to soften the backlash; and an india-rubber spring above gives a double action.

MM. Rothschild Brothers, Witkowitz, Moravia, exhibited a model of a 4-ton single-acting hammer. By means of three cams on the back of the tup acting on the valve, as in Messrs. Thwaites & Carbutt's hammer, the steam admitted below the piston is cut off at different elevations, to vary the stroke. The maximum stroke is 40 inches.

The Austrian States Railway Company exhibited drawings of the hydraulic forging press, the invention of Mr. J. Haswell, of Vienna, for forging iron and steel by hydraulic pressure. The metal operated upon is pressed between the flat faces of the hydraulic ram and a fixed anvil, or it is squeezed into moulds, and thereby brought into any required shape at one single operation. The difficulties that had previously to be overcome in applying a hydraulic press for forging iron, were caused by the exceedingly slow motion of the ram, which in most cases allowed the iron to cool too soon. This is obviated in Mr. Haswell's machine. The hydraulic ram is operated upon by the downward pressure in the main cylinder, the water being admitted by valves which open a communication between the cylinder and a reservoir filled partly with steam from the boiler, and partly with water, on which a piston is floated. The pressure of steam upon the piston in the reservoir forces the water into the cylinder, and the ram is moved rapidly down until it touches the iron, upon which it exerts a pressure equal to the whole pressure of the steam upon it. The cylinder is now put in communication, by shifting the valves, with two powerful force-pumps worked by a steam engine, and the increased hydraulic pressure so produced supplies the ultimate working pressure for squeezing the iron. The lifting of the ram, after having completed the operation, is effected by means of a differential piston connected to the first piston, on which the force-pumps are brought to bear. The ram is thus lifted, and the water from the main cylinder returns at the same time to the reservoir.

M. L. Schwartzkopf, Berlin, exhibited a hammer, in which the length of stroke is not varied, but the force of the blow is varied by wire-drawing the steam, and causing the hammer to move more slowly. The motion for the valve is derived from a stud fixed on the tup, which plays between the jaws of a forked lever in connection with the valve, striking them

alternately, as in Mr. Rhodes's hammer, but without his means of varying the stroke. The anvil is bedded on water, and may be raised or lowered to suit the work, as in Imray & Copeland's hammer.

CHAPTER XXIV.

CONCLUSIONS ON THE MACHINE-TOOLS EXHIBITED.

There is considerable diversity in detail in the machine-tools exhibited, but machinists are approximating to common types of structure and workmanship. Sliding surfaces are scraped, screws are uniform, frame-castings are hollow; all lathe-beds are of cast-iron, they are all planed; headstocks are alike, they have back-gear, conical bearings, and sliding spindles. Screws are all cut by screws; wheel-lathes have all double face-plates, with circular racks on the back to drive them; and they are all adapted for working singly, simultaneously, or conjointly. The tables of planing machines all move on wedge-troughs; they are moved for the most part by rack and pinion, and they have a quick return. Shaping machines are all made with a quick return, and slotting machines are not. Vertical drills, have a descending feed, and horizontal cone-pulleys to drive them. Above all, machinists are unanimous in the application of self-acting feeds.

In these and in many other particulars the machine-tool engineers agree. But in several important respects they continue to differ. Yet it is important to remark that differences or varieties may exist, and will probably always exist, which only reflect the habits of thought and the customs of practice, and which may justly be accepted as mechanical equivalents. The ultimate purpose of a metal-cutting tool is to make a continuous cut by pressure in lieu of chipping by blows, in one of two modes;—in a straight line, by the reciprocation of the work or of the cutter; or in a circle, by its revolution;—and it affords powerful testimony to the inventiveness of English engineers that so simple an abstraction can be embodied in such a variety of machines.

The following general observations are founded upon, and have reference to, the machine-tools exhibited.

Lathes.—Of the cutting-tools, the lathe is the most ancient and the most serviceable. The first and most natural function of the lathe is to form a truly cylindrical body, by means of the rotation of the spindle, and the sliding or traversing of the cutter in a direction parallel to the axis of rotation; but it is employed, in addition, for cutting screws and for surfacing or sliding the cutter at right angles to the axis of rotation across the bed, to form flat disc-surfaces. Conical bearings, it is agreed, are preferable to cylindrical bearings for the spindle of the fixed

headstock, partly for the sake of resisting the end-thrust, but chiefly to admit of a ready means of taking up the wear and slack of the bearings by lock-nuts at the "tail" of the lathe. Lock-nuts are also applied to the spindle to intercept the thrust, with a flat bearing upon the headstock; dispensing therefore with the "tail-pin," which was universally applied to take the end-thrust of cone-spindles with cylindrical bearings before conical bearings came in. This is a neat plan, and is convenient for the adjustment of the change-wheels; but the lock-nuts are liable to shift and get loose by the friction of the end-thrust, and to act properly they must be screwed with perfect truth, to insure their taking a breadth of bearing. In some lathes, accordingly, the tail-pin is applied, in conjunction with conical bearings, to take the end-thrust, with lock-nuts to take up the slack. To accommodate the change-wheels in lathes with tail-pins, a system of small carrier-pinions is in some lathes applied to take off the motion from the spindle, clear of the tail-pin frame. By another plan, in which the tail-pin frame is made with widely-spaced standards, on one of which the tail-pin bracket is hinged, and may be readily removed, large change-wheels may be placed direct on the cone-spindle.

The traversing motion for cutting screws is, in all lathes, derived from a screw. The same screw is also, in some lathes, employed to traverse the slide for ordinary turning, and to afford a fulcrum for a pinion, to traverse the slide quickly by hand. In others, a rack-and-pinion are provided exclusively for quick traversing; and in others, again, the rack-and-pinion motion is employed also for sliding, the screw being retained for screw-cutting. The first-named plan, with the screw alone, is decidedly the simplest, with the fewest number of parts; but with the application of the rack and pinion for sliding and traversing, the guide-screw is kept longer true for cutting true screws. The question with respect to the guide-screw is not considered to be one of slight wear, but that there should not be any wear at all. A neat means of reversing the traversing motion of the carriage, by the interposition of a carrier-wheel by a hand-motion, is generally employed in slide-lathes. The design of the duplex-cutters, applied at opposite sides of the work, for taking two cuts at once, is excellent; though an objection is made that the following cut is liable to follow the irregularities of the leading cut in a long or slender piece of work. There is less objection to the plan of applying both the cutters to the same side of the work.

The quick drawback motion for the cutter employed in cutting screws is useful, if properly applied. The method of the excentric, for setting and withdrawing the cutter on dead centres, is simple and good. It requires no supervision, as it cannot spring out of position.

The application of conical friction-surfaces for avoiding undue strain in working the self-acting motions of the slide, in the lathes of Messrs. Shepherd, Hill, & Co., is note-worthy, as it supplies a means of preventing the breakage of machinery from neglect or accident.

The addition of a special motion for special work to a general tool, as in the cotter turning-lathe, is of doubtful advantage; for, though the additional cost may be moderate, yet, when the same motion may be worked out simply and effectively on a smaller and separate machine, it may be better to reserve the larger tool for its own proper work if it can be fully employed.

Double Face-plate Lathes.—The double face-plate lathe, originally the invention of Mr. Joseph Beattie, was differently constructed, with one, two, and three driving cone-pulleys. With one cone, the cone-spindle is placed at the back, from which all the motions are delivered to the face-plates at their circumferences by means of gearing, with sliding pinions. With two cones, the duties are divided: one for working on large diameters, through the face-plate rack; the other for small diameters, through a spur-wheel on the spindle. The single-cone pulley has less mechanism, with the steadiest motion, acting entirely through the circumference of the face-plate; but with the duplicate cone-pulleys, two separate motions can be taken off at once—one for each face-plate—and at suitable speeds. By the addition of the third cone-pulley, applied to the following headstock, an additional quick motion can be had for acting on small diameters; and the lathe beneficially becomes, practically, two independent machines.

The circular rack on the back of the face-plate is either cast or bolted on. The single casting makes a perfectly good job. With external teeth, the rack may be extended to the extreme diameter of the face-plate, giving a good steady purchase on the face-plate; but to get rid of the inconvenience of crossing the belt with treble gear for the slowest speeds, the circular rack of a heavy break-lathe has been made with internal teeth. The motion is no doubt very smooth, and probably the teeth of the rack may be made of a stronger form than when exterior; but, on the contrary, the teeth of the pinion are likely to be weaker, being narrowed near the base, and the internal rack diminishes the purchase on the face-plate.

Planing Machines.—The bed of the planing machine is traversed by means of a screw, or by means of a rack and pinion. The motion of the screw is perfectly smooth and perfectly regular, and it stops the table dead for reversing without straining the driving-gear. When originally introduced, the screw was unquestionably superior to the rack as it used to be made—as a propeller for the table; its power of wearing well, moreover, is, for that purpose, first-rate. The driving-gear for the screw is necessarily

placed at one end of the machine, out of the way, and, it is needless to add, facilitates the operation of the attendant, when compared with the side-gear required for working the rack-motion.

The rack-motion, originally vibrative and otherwise defective for the production of a perfectly straight cut, has been materially improved. To adapt the imperfectly-formed teeth of the racks formerly made, for straight cutting, by dividing and reducing the jar, they were originally, and are now, in some instances, divided into parallel rows, with repeating teeth, in duplicate, in triplicate, or even in quadruplicate; and probably this was the best that could be done with them, in the want of a correct form of tooth. But, that the repeating rack may work as desired, the teeth of both the rack and the pinion must be formed and pitched with absolute uniformity, otherwise the motion fails, and the teeth are liable to be broken. The form of the teeth, therefore, has been the subject of careful revision, on the principles announced and ably expounded by Professor Willis and others, and a correct form of tooth has thus been matured. With correctly-formed teeth, then, the single rack, whilst it preserves the full strength of the teeth, transmits a very smooth and steady motion to the table, sufficiently so, probably, for almost every practical purpose. The rack, besides being easily made, is necessarily, by the fact of its being bolted to and constituting a part of the table, rigidly sustained, and affords a firm bearing for the thrust of the propelling pinion. The screw, on the contrary, is necessarily suspended between its extremities with the single aid of the nut in which it works, and which connects it to the table for propulsion; and it is, when of considerable length, liable to be twisted or vibrated out of its right line by the resisting strain of a heavy cut. Users of tools work their machines to their maximum capacity, and heavy cuts are in vogue to expedite the work. The policy of heavy cutting may be right, or it may be wrong; but manufacturers of planing machines, as of other tools, have been driven to the adoption of massive proportions and rigid connections, to support the strains. In one planing machine the driving pinion under the rack,—overhung in other machines,—is supported by a bearing in the frame on each side, to extinguish all vibration. The main condition of steadiness and smoothness of motion, besides massiveness and strength of framing, is weight and stiffness in the table. The rack-table, it may be added, may be placed lower than the screw-table, as the latter is formed to clear the driving-gear at one end of the bed; and further, the propelling power is applied to the rack-table at a stationary point in the frame-bed, just below the cutter, or the point of resistance; whilst, in the screw-table, the power is applied to the travelling nut, from which it must be transmitted

through the table towards the cutter. In the former, the power is advantageously applied at the shortest distance from the resistance; in the latter, it is advantageously applied at the centre of the mass of the table:—these are the respective advantages.

The reversing or double-acting cutter, to cut both ways, is applied to Messrs. Whitworth & Co.'s largest planing machine. In their smaller machines, and in all the other planing machines, the single-acting fixed cutter is applied, with a quick return. The double-acting cutter was originally applied to save the great loss of time in returning at the same speed as in cutting; as, of course, double the quantity of work was done by the double-acting cutter in the same time whilst at work. But, with a quick return at three times the cutting speed, which is now applied to other machines, the double-acting cutter can do, at the utmost, only a third more work in the same time;—actually less than a third more, reckoning the time for setting and fixing work on the table, and allowing for work to which the double-acting cutter is inapplicable, and for other constant quantities. The capacity of the single-acting machine is further increased by the application of a second cutter and slide. By means of stops acting on levers of different lengths, the motion of the rack-table is reversed with the same ease and certainty both ways, and with sufficient precision for the purpose.

The cutter-box, with double-revolving adjustable slides, in Messrs. Fairbairn & Co.'s machine for planing inclined surfaces, is worthy of notice, as an addition to the capacity of the tool. It involves a greater number of pieces in the carriage, and a greater projection of the cutter from the face of the transverse slide.

Shaping Machines.—Shaping machines, like planing machines, cut only one way, and are driven with a quick-return motion, excepting for the smallest sizes. The quick return is performed in a simple and elegant manner by means of the slotted link vibrating on its lower end. The connection and transmission of power to the ram is made at one side of it, in some instances; and, in others, at the centre line, in the direction of the cutting strain. The lateral connection strains the ram obliquely, and tells upon the slides by wearing them diagonally; and with an overhanging cutter, a long stroke, and a heavy cut, the cut is not likely to be so nearly correct as when the connection is central. Rams are usually constructed hollow, and of considerable breadth, with a broad base. But the wider the ram, the more injurious is the oblique action, with a lateral strain; and the solid ram, consisting of a plate on edge, guided in V slides at top and bottom, admits of the lateral connection being applied near to the cutter-line.

The bed of the shaping machine requires to be of great depth to ensure a stiff and unyielding support for the tables. In most cases, the depth is insufficient to resist the overhung

strain of the cutter. The tables, also, must be strongly bracketed; and to ensure to them, as overhanging tables, the greatest degree of stiffness, the stiffening flanges or brackets are, in one or two cases, made to a parabolic outline. The same, or nearly the same, degree of stiffness is required in the shaping machine as in the slotting machine, though the latter possesses the advantage of the table being bedded on the foundation of the machine.

For circular shaping, the double-cone spindle is in some cases fortified by a bracket from the lower part of the bed, which is essential in heavy cutting. In one instance an alternate socket is provided for fixing the spindle at a different elevation to receive work of different diameters.

Slotting Machines.—Slotting machines for vertical cutting are the equivalents of shaping machines for horizontal cutting; but they are necessarily made with a proportionally greater overhang. Acting usually upon the shorter dimensions of objects, they must have capacity for receiving them in their longer dimensions. They are therefore usually constructed solidly, the base and the frame being united in one casting, to the circuit of which the strain is confined. The large cranked-axle slotting machine of Messrs. Smith, Beacock, & Tannett has the base cast separately, and bolted against the side of the frame. A firmer junction would have been made by bolting down the frame upon the base. The tables of slotting machines are placed solidly upon the base, and receive the vertical thrust of the ram without leverage. The feed is taken off in two modes,—by horizontal and by vertical cams on the disc-shaft. The horizontal cam admits of a compact connection—by means of an upright rocking-shaft—to the table; but the vertical cam affords, with every facility for adjustment, the most simple and direct through connection for the feeds. Messrs. Fairbairn & Co.'s slotting machine with a vertical cam contains an example of a simple, compact, and convenient feed-motion,—in few pieces, out of the way, the feeds independently adjustable, and with a ratchet-motion to each.

The table is in most machines fitted with swivel-bearings, to admit of its being inclined for angular slotting. It is sufficient for this purpose that the table should be made to swivel upon the shaft of the worm applied for the circular feed.

The ram works vertically between adjustable bevilled slides, where it is subject to strains of every kind in every direction. It is of prime importance that the ram should be guided firmly in a path truly perpendicular to the table, and this is well provided for in the new continuous slide-bearing. In working the ram from the disc behind it the power is necessarily applied to it out of the vertical line of resistance through the point of the cutter. Of course, the nearer it is the less is the obliquity of the pull on the

ram, and the better it is for the slide; but in some tools this consideration appears to have been disregarded. The overhang of the driving stud-pin in the disc affects somewhat similarly the bearings of the disc-shaft, in exciting by leverage a frictional strain upon them. This strain, though it does not by the wear arising from it necessarily affect the correctness of the work, is, in a few of the machines, counteracted by applying a bearing on the rim of the disc to oppose the upward strain. In one or two cases, the bearing is made with means of adjustment for wear, which is the most serviceable mode of applying it. With a long disc-shaft, where the cone is placed upon it for back-gear, the leverage strain is of little moment.

Vertical Drilling and Boring Machines.—The frame of the vertical drilling machine, like that of the slotting machine, overhangs the work; but the duties are lighter, and the table, instead of being solidly bedded, is hung laterally from the frame, with a swivel joint to throw it aside when very large work is brought to the machine. The system of applying the vertical slide for the table to the front of the frame with a couple of pivot-bolts to swing the table is simple and good. It combines the least overhang with the most room for large work on the table.

The application of conically-adjustable bearings to the spindle is a refinement of recent introduction for keeping the spindle truly central and vertical, in taking up the slackness by wear. The vertical feed by screw is very well worked out in one machine where the screw is steadily held in double bearings above and below the nut. The screw-feed steadily sustains the spindle without vertical play; and as the purchase of the feed lies chiefly in the screw, the gearing for working it is not so heavily strained nor so liable to fracture as in the rack-feed.

The frictional-gear drilling machine is an ingenious and convenient combination of four drills of graduated sizes, suitable for small work. Frictional gear absorbs a good deal of power, but for a machine of small dimensions this is not a material objection.

Radial Drilling Machines.—By the method of hanging the jib and jib-bracket, by causing the bracket to embrace a round central column the resisting stiffness of the standard is of course the same for any position of the jib; but as the movable parts are necessarily overhung to a greater extent when made to revolve on the column as a pivot than when hung upon one side of the column the connections require to be made considerably stronger in the former case, to insure the same degree of stiffness as in the latter, with an equal extent of range radially; for, in explanation, it may be stated that the unavoidable expansion of the base of the column in the former case, to afford a

firm connection with the base-plate, prevents the work from being placed near enough to the column to utilise the horizontal slide-space which is saved in the jib by hanging it directly upon the column. Moreover, the laterally-hung jib-bracket being lighter, and being hung on pivots or bearings of smaller diameter than those of the other—hung upon the column—is more easily manipulated.

The standard with the lateral attachment, when cast hollow and circularly, is practically of the same stiffness in any position of the jib.

With the telescopic driving-shaft for the jib a more compact and simpler system of gear may be employed than with the straight thorough shaft; but in either case the overhanging and exposed sliding-shafts employed in one of the machines may be avoided.

A self-acting appliance for raising and lowering the jib by power is useful; in this, a continuous motion is more expeditious than an intermittent motion.

Traversing or Slot-drilling Machines.—The traversing of the drill in equal stages by uniform feed cannot be effected without the intervention of gearing. A pair of elliptical toothed wheels or an elliptical and an eccentric circular-wheel gearing together, give a nearly uniform traverse; and of the two, the traverse by the former is probably the more nearly uniform; but it appears to require the aid of a couple of cam-guides to retain the elliptical forms in gear. By means of the uniform feed, compared with the variable feed from an ordinary crank-motion, more work may be done in the same time.

The greatest difficulty with machines of this kind is to keep the drill steady and inflexible—free from vibration—in cutting deep mortises. This object is sought to be accomplished in one case, by staying the drill-spindle in a stout octagonal slide, which descends with it, and exposes only so much of the spindle as is needful for executing the work. In a second plan two shorter drills are applied from the opposite sides to cut out the slot, meeting in the middle of it, by which not only greater stiffness than in any form of single drill is obtained, but also twice the quantity of work by double action in the same time. The rate of production is understood, in practice, to be something more than double that of a single drill, as the double drills, being shorter and stiffer, may be driven faster than the single drills. The double drills are driven direct by means of cone-pulleys on the spindles, which are horizontal.

The work done by the double drill is correct and smooth, and is turned out finished from the machine, without the aid of the rosebit for removing inequalities, such as arise in the work done by the single drill.

Circular Cutters.—The chief objection to the use of circular cutters for cutting metal has

been the unsatisfactory manner and the great cost of making them; but this objection is being overcome, as no greater mechanical difficulty has been found in constructing machinery for the purpose of forming the cutter than for cutting the teeth of wheels. Take, for example, Messrs. Fairbairn & Co.'s pantograph cutter-forming machine, by means of which the teeth of the cutter are both divided and completely formed. It is true that machines employing revolving cutters have long been used for some purposes, but they have generally been confined to a class of work where single-pointed cutting-tools would be inapplicable. In a few instances, shaping machines with circular cutters have been used for finishing the surfaces of machinery with marked success, doing, to the extent of their capacity, three times the work of a planing machine, self-acting, requiring little management, and working six months without sharpening. The work turned off by properly-made circular cutters is very superior, especially for intricate forms; and, when frequently repeated, it reduces the skilled labour and the cost of production.

Screwing Machines.—The conical dies are efficient for the purpose of screwing bolts with a good thread in one cut, truly, easily, and rapidly, without unnecessarily straining or squeezing the metal. The pitch of the screw to be cut being, on this system, correctly started from dies of the same diameter, the dies progress naturally in the formation of the screw without the risk of elongating the bolt; and any number of screws may thus be cut identical in form and dimensions.

On the same excellent principle the chasing lathe is designed; it turns out good and superior work, like the work of a screw-cutting lathe rather than that of a screwing machine. For cutting angular-threaded screws, the chasing lathe will do much more work than the screw-cutting lathe; but as each bolt must be centred and suspended, it cannot be expected to rival in quantity of production the best forms of screwing machines.

Steam-Hammers.—The application of the principle of double action to steam-hammers, in which steam is admitted to the upper side of the piston, to accelerate the fall of the hammer and increase the number and force of the blows, has considerably increased the efficiency, and enhanced the value, of the steam-hammer. The credit of introducing the double-acting hammer is generally conceded to Mr. William Naylor, whose hammers were exhibited by the Kirkstall Forge Company. The principle was first announced by the late Mr. Condie, who, in his patent of 1846, specified the admitting of steam under the piston of this moving cylinder, to increase the force of the blow; but it was left for Mr. A. C. Wylie, his successor, to work it out

in moving-cylinder hammers, examples of which were exhibited by him, though not until after Mr. Naylor had applied it to the ordinary hammer.

The "moving-cylinder" hammer, invented by the late Mr. John Condie, and exhibited by Mr. Wylie, is an important modification of the steam-hammer as originated by Mr. Nasmyth, and variously exhibited.* The breakage of the piston-rods of ordinary hammers, particularly when working by double action, has been a frequent source of trouble, and several constructors have for that reason gradually enlarged the rods, and forged them in one piece with the piston—arriving practically at an elongated hammer, further extended by Messrs. Morrison & Co., through a stuffing-box in the top of the cylinder. But, independently of the liability to new kinds of disturbance, arising from the great length of the hammer-piece, the elevated centre of gravity, and the liability to vibration, particularly when the lower portion is not guided, the elongated hammer is imperfectly adapted for irregular forging, in which dies are employed, with oblique action and side blows. For this purpose the moving cylinder, in a broad mass, with a low centre of gravity, and thoroughly guided, has proved very efficient and durable.

The balanced or equilibrium-valve, in some hammers, is a good feature; it is, in fact, indispensable for the production of fine work by hand, for which prompt and lively action of the valve is needful.

In the self-acting hammers of Nasmyth, and Naylor, and Condie, worked by means of the kicker-bar, or swing-weight, steam is not admitted for lifting the hammer until the force of the blow is expended upon the metal.

Attempts have been made to prevent the entrance of any steam below the piston until the blow is struck, without the use of the swing-lever or "kicker-bar." This was only effected with the steam-wrought piston-valve in Joy's hammer, exhibited by Messrs. Carrett, Marshall, & Co. This hammer is ingeniously detailed, and it is said to be susceptible of the most exact regulation.

The application of hydraulic pressure for forging or moulding iron into particular forms, introduced by Mr. Haswell, is likely to be usefully available for many purposes.

Punching, Shearing, and Riveting Machines.—By the application of the oblique shears in the ordinary forms of shearing machines, bars may be

* An erratum has crept into the description of Condie's *Double-acting Hammers* (page 202), discovered since it was printed off. They are not *single-acting*, as erroneously described, but *double-acting*, with means of diminishing the force of the blow, or even to prevent the hammer touching the anvil. The admission of air into the cylinder does not occur when the hammers are worked by double action. The valves, also, are not necessarily *worked by hand*, but are fitted with *self-acting gear*.

conveniently cut off to any length. But the rocking-lever punching and shearing machine of Messrs. De Bergue & Co. is the most simple and convenient for working at, and is likely to prove the most durable. It is partially a reversion to the old lever punching machine; but it and all the other forms of punching machine exhibited, wanted the best feature in the old lever form—the cam-motion for the quick return.

The steam-riveting machine of Messrs. Cook & Co. is very simple and compact, very ready, and very efficient. Worked by hand, it may be

employed without the loss of time attendant upon self-acting machines closing at regular intervals, without regard to the exigencies of the work. It differs from Garforth's direct-action machines, exhibited in 1851, in the intervention of a lever between the piston or trunk and the heading-die; which incurs, no doubt, a greater number of wearing parts, but, on the contrary, facilitates the accumulation of momentum in the moving parts for the final blow, which is important for the purpose of forming a rivet-head.

SECTION II.

MACHINES FOR WORKING IN WOOD.

CHAPTER I.

INTRODUCTION.

Wood-working machinery has made great progress during the last ten years. In 1851, machines of this class were exhibited chiefly, if not solely, by Mr. Furness, of Liverpool, constructed by Messrs. Fay & Co., of Cincinnati, with wooden framing, in the style of the "labour-saving" machines of the United States. In 1862, several collections of wood-working machinery were exhibited, chiefly English, made with strong iron framing, and with several novel applications. The method of the model, or the "former and tracer" for copying and shaping irregular forms in wood, fac-similes of metallic or wooden models, derived probably in the first instance from the United States, has been variously and successfully employed for working in wood as well as in iron. Several ingenious adaptations of the principle were exhibited by Messrs. Greenwood & Batley, one by Messrs. Cox & Son, and one by Messrs. Bernier & Arbey, of Paris.

Several band-saws—a comparatively novel class of machines—were exhibited in action. M. Perin, of Paris, invented, and was the first who brought these serviceable machines into practical use; and their introduction into general use in England is due to General Tulloch, lately Director of the Royal Carriage Department at Woolwich Arsenal, who, with the heads of the various departments at the Arsenal, made a visit of inspection to the Paris Exhibition of 1855, and purchased and brought over an ordinary band-saw exhibited at work by M. Perin. It became a favourite machine, performing wonderful feats of sawing, and superseding the vertical whip-saw. Other band-saw machines of more substantial construction were ordered, suitable for the various requirements of the establishment, and

new applications of them were made, with success. The example set at Woolwich was quickly followed at other wood-working establishments in various parts of the country, and hundreds of band-saws were quickly at work. The band-saw exhibited in action by M. Perin, in 1862, became celebrated for the beauty and delicacy of the work executed by it—intricate monograms, involved tracery, and the like. A band-saw exhibited by Messrs. Worssam & Co. was kept steadily at work in sawing up specimens of wood to exactly identical dimensions, for purposes of experiment at the Department of Science and Art.

CHAPTER II.

WOOD-WORKING MACHINES EXHIBITED BY MESSRS. S. WORSSAM AND CO., LONDON.

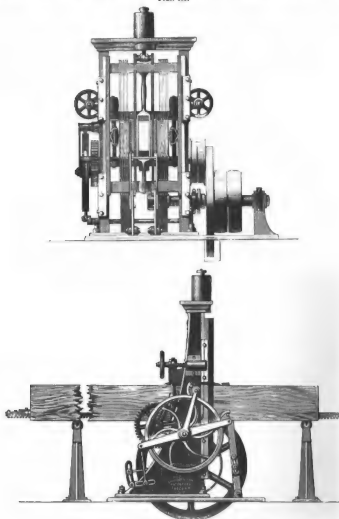
Messrs. Worssam & Co. exhibited a series of tools for working wood, in which great strength is combined with good, solid workmanship.

1. *Portable Deal-Frame*.—This frame is designed chiefly for builders' and contractors' use, and will cut two deals 14 inches deep by 4 inches thick and 24 feet long, into thin boards. It is fitted for ten upright saws, which are fixed in a frame driven from below. The whole of the working parts are placed on a single cast-iron baseplate. The connecting-rod is worked from a single crank, and is looped to clear the rack, which passes through it, and it is attached to the swing-frame at the top. Thus, the connecting-rod can be had of sufficient length without requiring the crank-shaft to be placed underground. The "silent feed," patented by the

exhibitors, is a good and simple arrangement to supersede the usual ratchet-wheel, and consists of a grooved wheel, into which a friction-quadrant or paul on the end of a lever is dropped, and bites, to give the advance for

the feed. By this means, as the paul bites anywhere, the rate of advance of the timber may be regulated according to its depth with any degree of nicety, and the feed works without noise. An air-cylinder, or more correctly

FIGS. 183.



PORTABLE DEAL-FRAME, by Messrs. WOODMAN & CO., London.

a vacuum-cylinder, is applied at the top of the fixed frame, for the purpose of balancing the weight of the swing-frame, to which a piston, accurately fitting the cylinder, is connected.

With the descent of the frame, and the piston with it, a vacuum is formed on the upper side of the piston, and the resistance of the atmosphere on the lower side balances the weight of the

moving frame. A valve on the upper side of the cylinder, opening outwards, sets free any air that may leak above the piston. There is no doubt that the vacuum-cylinder is in the proper position for making a correct balance, and, assuming that it can be easily kept in good order, it is better than the counterweighted fly-wheel. The deal-frame makes 250 strokes or cuts per minute, and the rate of feed is variable from 9 inches to 2 feet per minute, according to the number of saws in use. With an average number of saws, it is said to be capable of cutting 100 deals, 12 feet long, per day. The lateral pressure-rollers are retained by means of laminated springs, which are steadier and more compact for that purpose than dead weights (figs. 183).

2. *Band-Saw*.—This machine is adapted for cutting out wood, up to 12 inches deep, in curves or sweeps of every variety. The endless saw works over a pair of pulleys 30 inches in diameter, making 400 revolutions per minute. The

angle, and the saw runs between packing-boxes, with screws for adjusting the packing, to steady the saw, and keep it to its work (fig. 184).

3. *The General Joiner*.—This novel machine is so called on account of the considerable variety of joiners' work which can be executed by it, as sawing, grooving, tonguing, rabbeting, tenoning, moulding, boring, cross-cutting, and squaring off. The work is done by means of a circular saw and an auger fixed on a horizontal spindle, one at each end. The saw is 15 inches in diameter, and cuts 6 inches deep; the augers, which are changeable, bore up to a 2-inch hole. The spindle is at a fixed level, and the usual speed is 1600 turns per minute. The tables or benches, of which there are two, one for the saw and one for the auger, are levelled independently of each other, to suit the work. The whole machine stands upon one baseplate (figs. 185, page 214).

The table is capable of taking in a 16-inch saw, and is worked with a rising and falling motion for grooving, tonguing, and rabbeting. It is also fitted with a light cast-iron slide-plate, working in a groove, for cross-cutting, squaring, cutting the shoulders of tenons, and such work. Grooves are formed by means of a "drunken saw" on the spindle, that is, a thin blade set on the spindle, out of truth, in place of a thick saw, so as, when revolved, to cut a groove of the required width. Beads or mouldings on window-frames may be cut by moulding-"irons" fixed on a small cutter-block. The spindle is bored up at one end to take the augers. A simple arrangement is provided for cutting wedges for joiners' work, easily and with expedition. The various auxiliary parts of the general joiner may be briefly enumerated:—

1. The fence on the saw-bench, which may be slewed to any angle, for working stuff on the bevel;
2. The small sliding table on the saw-bench, to carry work over the saw;
3. The tenoning cradle or cramp, which slides on the fence to hold work up to eight inches square, for tenoning, &c.;
4. The wedge-cutting plate, with a spring pad;
5. An extra flat to insert in the table, with moulding blocks for moulding, sawing, and grooving.

The auger-boring bench has three movements of adjustment,—vertical, horizontal, and circular.

The novelty of this machine consists in the variety of simple appliances, which, combined with a circular saw-bench, make a machine capable of performing almost every operation required by a joiner.

4. *Roller-Planing Machine*.—This machine is

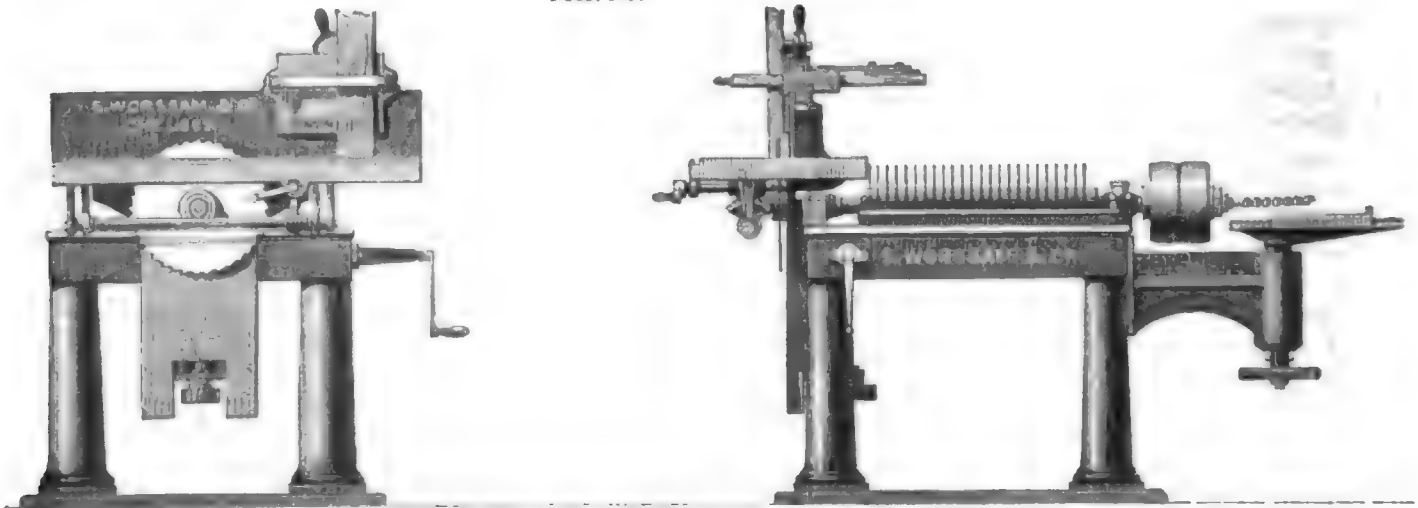
FIG. 184.



HAND-SAW, by Messrs. Worsam & Co.

pulleys are accurately turned and balanced, and are covered with leather, upon which the saw works smoothly, the upper pulley being adjusted by means of a lever and screw, for keeping the saw at a uniform tension. The table is made to cant either way, so as to cut the wood at any

FIGS. 185.



GENERAL JOINER, by MESSRS. WORSSAM & CO.

of unusually large size, adapted for planing, grooving, tongueing, edging, and thicknessing, at one operation, boards or planks up to 15 inches wide by 6 inches thick, and is chiefly useful to large workers in wood. It has one speed—50 feet per minute. There are two pairs of large feed-rollers, 2 feet in diameter, turned with a smooth surface. They are made unusually large, in order to get a good grip or hold by adhesion on the wood;—the first pair to drag it forward, and the second to pull it out. The upper rollers are placed considerably apart in a frame, and they are loaded for adhesion by means of four weighted levers. All the rollers are driven by gearing to give the feed, and consequently they all exert a propelling force. A good deal of heavy spur-gearing is employed for the purpose.

A cast-iron planed straight-edge is fixed on the table at one side, to guide the material. The timber is cut on the four sides by cutters, placed successively below, at the sides, and above. The under cutters are placed between the first and second pairs of feed-rollers, and consist of a revolving under cutter, to adze or dress, and level the lower side of the timber, followed by two plane-irons fixed at an angle of 45° . The material is held down over these cutters by weighted rollers, with bearings on the feed-roller frame. The under cutters are fitted into planed cast-iron drawers, which can be taken out sideways from the table when required, and replaced, without stopping the machine. A third plane-iron can be substituted for the revolving-cutter.

Beyond the second pair of guide-rollers, the side cutters and the upper cutter—revolving cutters—are applied in succession. A guard-plate is applied across the table behind the side cutters, and is serviceable in preventing chips from the side cutters from entering the machine. The revolving cutters run at the same speed, making 3,500 revolutions per minute (fig. 186).

The chief novelty in this machine consists in the unusually large size of the smooth feed-rollers, of which there are only two pairs, but which, on account of their large size, can, it is said, propel

and feed the boards through the machine as easily as six pairs of rollers of the ordinary size. The advantage claimed for this arrangement is, that this machine may be made considerably shorter than it can otherwise be made (with smooth rollers); and that twisted boards, being thus confined for a comparatively small portion of their length, in passing through the machine, are planed and reduced to an uniform width and thickness throughout, with the least possible proportion of waste. The introduction of the revolving cutter for roughly planing the bottom side of uneven boards before being acted upon by the two fixed plane-irons, is also a novelty.

5. Small Moulding Machine.—This machine is designed to work on three sides, and to cut mouldings up to 6 inches by 3 inches, or two mouldings 3 inches wide. In this, as in the previous machine, there are two pairs of feeding-rollers, pressed by a weighted lever, between which the under cutter revolves. The side cutter is in advance, and the upper cutter follows last. The feed varies from 12 to 24 feet per minute (fig. 187, page 216).

6. Mortising Machine.—This ingenious machine is adapted for any kind of wood, and is peculiarly suitable for railway-carriage and waggon building. It is designed for cutting mortises of from $\frac{1}{2}$ inch to 2 inches wide. The novelty consists in the use of a square hollow chisel with four cutting edges, and an auger inside the chisel. The point of the auger projects slightly below the edges of the chisel, and seizes the wood in advance, whilst the auger revolves and bores a round hole. The chisel follows, and simultaneously cuts out and squares the corners and sides, thus completing a square hole. By cutting a succession of square holes running into each other, mortises of any length may be formed. In the sides of the chisel long slot-holes are cut, through which the chips made by the auger are expelled, that the cutter may by this means keep itself clear while at work, and remove its own core.

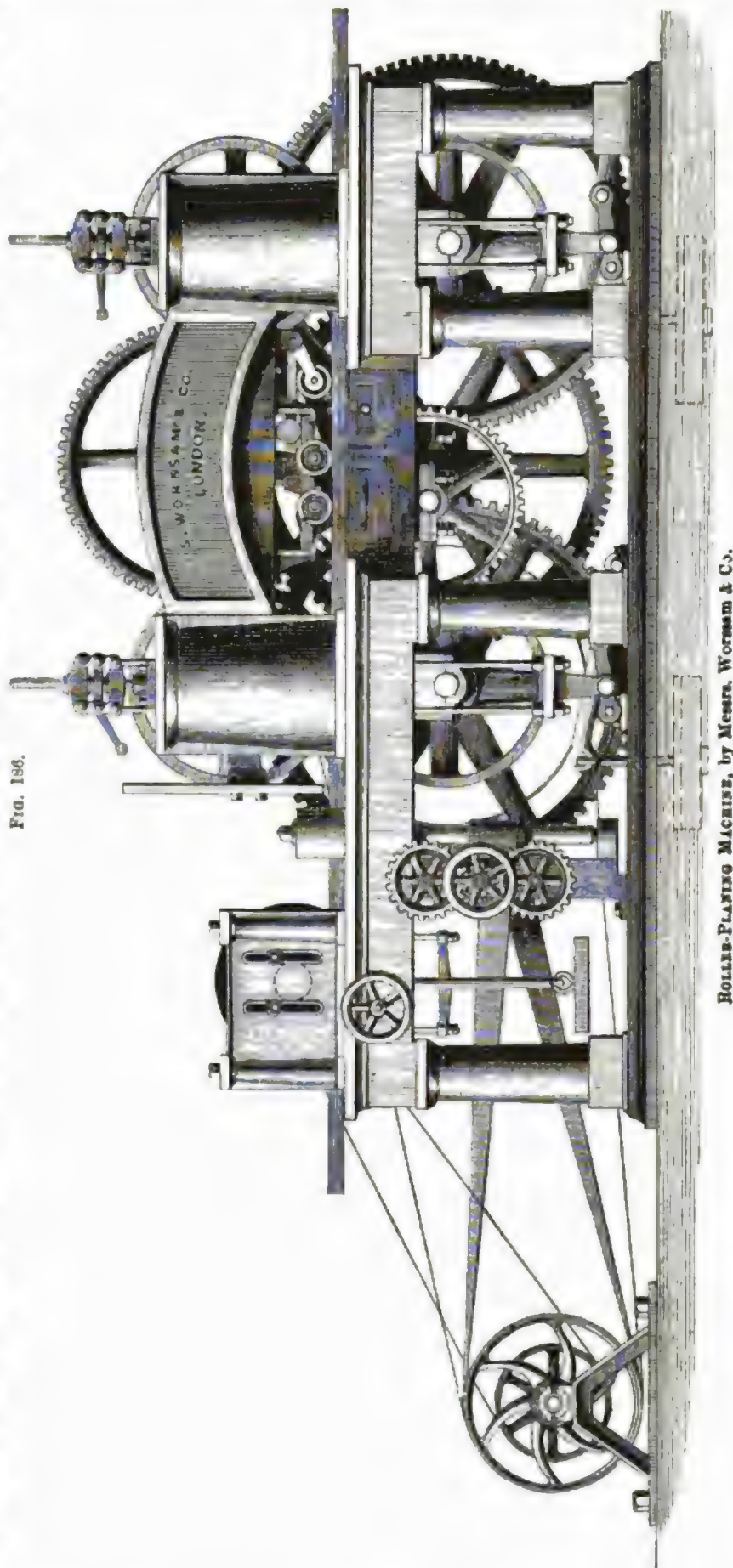
By a self-acting mechanism the cutter is brought down to the work, and it will cut a mortise 4 inches deep, or, from two opposite sides together, 8 inches deep. The feed is effected by means of friction-wheels, of which there are two sets, one for the feed downwards, driven by a cross gut-band, the other for drawing up the cutter at about three times the descending speed, driven by an open band. The driving friction-wheels are hung upon the ends of a shaft, which are eccentric to the shaft, and by means of a hand-lever one or other friction-wheel is brought into gear for the downward or the upward motion.

The table is made with three adjusting movements, horizontally and vertically, and is made to cant at any angle for working bevel mortises. A simple arrangement is applicable for mortising wheel-naves, with the alternate splay required for the spokes, in which a dividing-plate is employed to set out the distances on the circumference (figs. 188, page 216).

7. Double-Tenoning Machine.

—This machine is adapted for cutting double tenons in hard or soft wood, in scantlings up to 6 inches thick and 15 inches wide. It is provided with two revolving cutters, one above and one below, to form the outer surfaces of the tenons, and a "drunken" or oblique saw on an upright spindle, to cut out the interspace and form the inner surfaces of the tenons. The work is fixed on a sliding table, on which it is traversed successively across the revolving cutters and the saw. The table is steadied by a check-feather formed on the side next the cutters, which slides in a groove in the bed. The upper adze or cutter-block is made to shift on the spindle, the lower one being stationary, for cutting tenons differing in length in the same scantling, and the table is fitted with spring-stops as guides for the length of the tenon, superseding the process of setting out by hand (fig. 189, page 216).

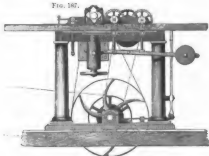
8. Cylindrical Gouges.—These gouges, on



Wilson's patent, are intended to supersede the ordinary gouges used in machines for surfacing and squaring-up timber. They consist of cylinders of cast steel, turned cylindrically, and bored conically. The lower edge is chamfered on the

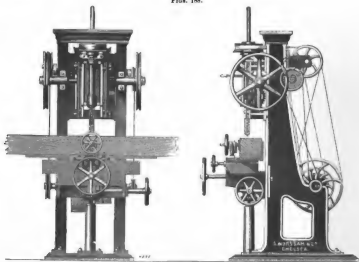
outer side, to form a cutting edge on the inner circumference all round. The gouges are placed at an angle in the circular disc, and the chips escape through the centre of the gouges, which are widened at the upper end for their free escape. When the gouge becomes blunt at the portion of the edge which is in action, or should it strike upon a nail, it may readily be turned in its socket to present a fresh cutting edge.

FIG. 187.



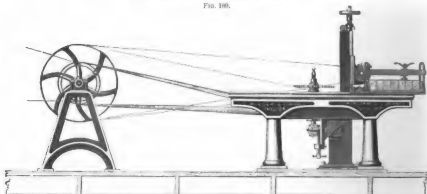
SMALL MOULDING MACHINE, by Messrs. Worsam & Co.

FIG. 188.



MORTISING MACHINE, by Messrs. Worsam & Co.

FIG. 189.



DOUBLE-THROWING MACHINE, by Messrs. Worsam & Co.

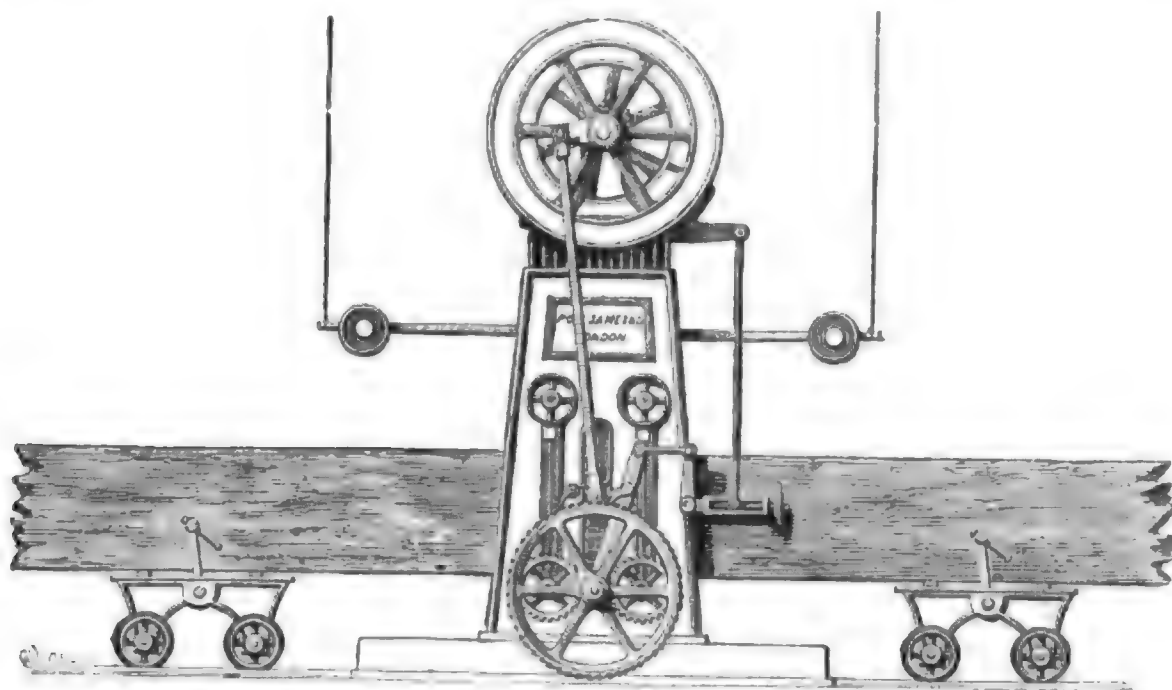
CHAPTER III.

WOOD-WORKING MACHINES EXHIBITED BY
MESSRS. POWIS, JAMES, AND CO., LONDON.

Messrs. Powis & Co. exhibited an assortment of machines of excellent workmanship, and combining a considerable degree of originality with efficiency.

1. *Combined Timber and Deal-Frame.*—This machine is adapted for cutting timber, either hard or soft, up to 26 inches deep and 24 inches wide, or deals 26 inches by 7 inches. The combination of these functions constitutes the novelty. The machine will take twenty-four saws, one inch apart, for cutting $\frac{7}{8}$ -inch fitches; but it was exhibited as a deal-frame. The timber is advanced by means of two fluted feed-rollers,

FIG. 190.

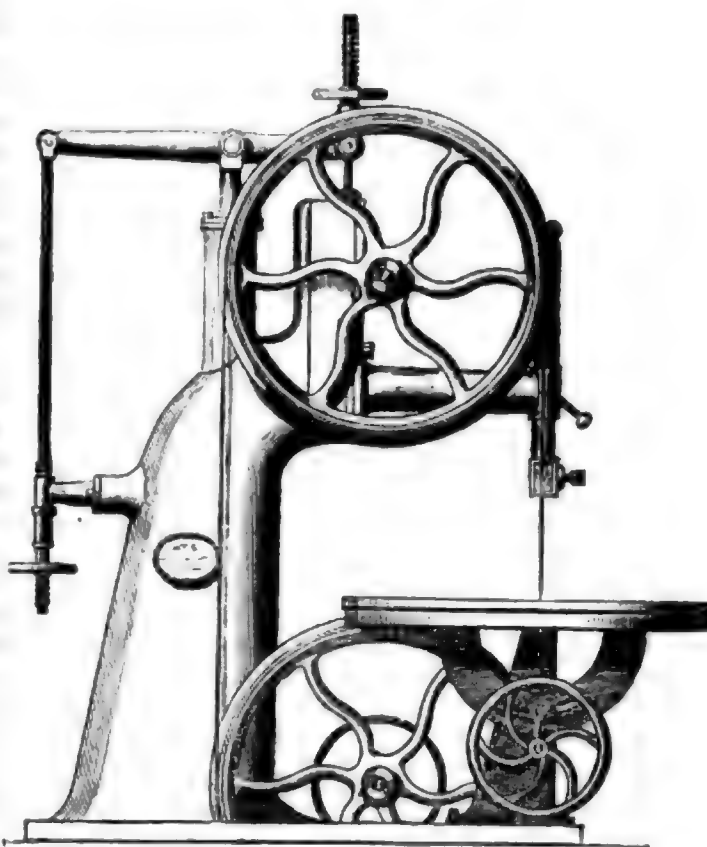


COMBINED TIMBER AND DEAL-FRAME, by Messrs. Powis, James, & Co., London.

and is kept steady by means of universal-jointed pressure-rollers at the sides and top, acted on by springs to suit inequalities of the surface. The frame may be driven from above at 140 revolutions per minute, or from below at 190 revolutions, by simply reversing the connections. The crossheads of the swing-frame are of steel, and the slides move in and are steadied by grooves. The swing-frame is counterbalanced by two flywheels, properly cored out, or hollowed, at one side, from which side rods are connected to the swing-frame at the middle of its height, which is the best point for connection (fig. 190).

2. *Band-Saws.*—Two band-saws were exhibited; the first, or smallest, had 24-inch pulleys, making 385 turns per minute; the second had 40-inch pulleys, making 360 turns per minute. The bearing of the upper pulley is adjustable vertically, controlled by a spring, the tension upon which, and through it upon the saw, is adjustable. As the saw contracts or expands by variations of temperature, the spring gives or takes, and the tension is rendered practically uniform. The use of the elastic bearing prevents breakage, as well as slipping of saws. The spring is a compound of steel and India-rubber, and though one material may fail the other continues in action. The table may be set at any angle for bevelled work. The frame of the machine is a

FIG. 191.



BAND-SAW, by Messrs. Powis, James, & Co.

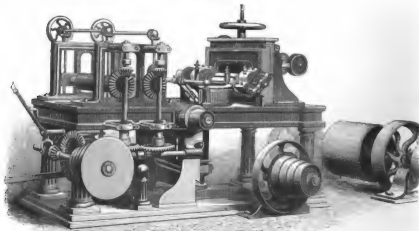
hollow casting; it is strong enough, but ungraceful, and is to be accepted as an introduction of the hollow-casting system of frame into wood-working machinery (fig. 191, page 217).

3. Planing Machine.—This is a simple and compact machine. It planes wood of any size up to 12 inches wide by $4\frac{1}{2}$ inches thick. It feeds by means of two pairs of rollers, 8 inches in diameter, placed near together at the entrance of the machine, of which the lower rollers are smooth and the upper ones are fluted, to increase the bite without applying excessive pressure. The weighting of the rollers is effected in a

simple manner, by means of a single weighted lever, with equilibrium-beams to distribute the pressure equally on the rollers. The upper feed-rollers only are driven, and from a four-speed cone on a transverse shaft at the end of the machine through three pairs of bevel wheels.

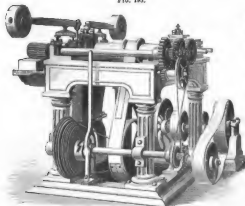
The wood passes, first, over the under revolving cutter to level the lower side of the wood, then past the side cutters, then under the upper cutter, and finally over a planing iron to finish the lower surface. The cutters are forged solid on the spindles. A disengaging clutch is applied, worked by hand, by which the feed may be instantly stopped if desired (fig. 192).

FIG. 192.



PLANING MACHINE, by Messrs. Fowle, James, & Co.

FIG. 193.



MOULDING MACHINE, by Messrs. Fowle, James, & Co.

In some recently-made machines the exhibitors have, for the purpose of increasing the bite and preventing slipping, applied gearing to turn the lower rollers, and have enlarged the upper rollers to 11 inches in diameter.

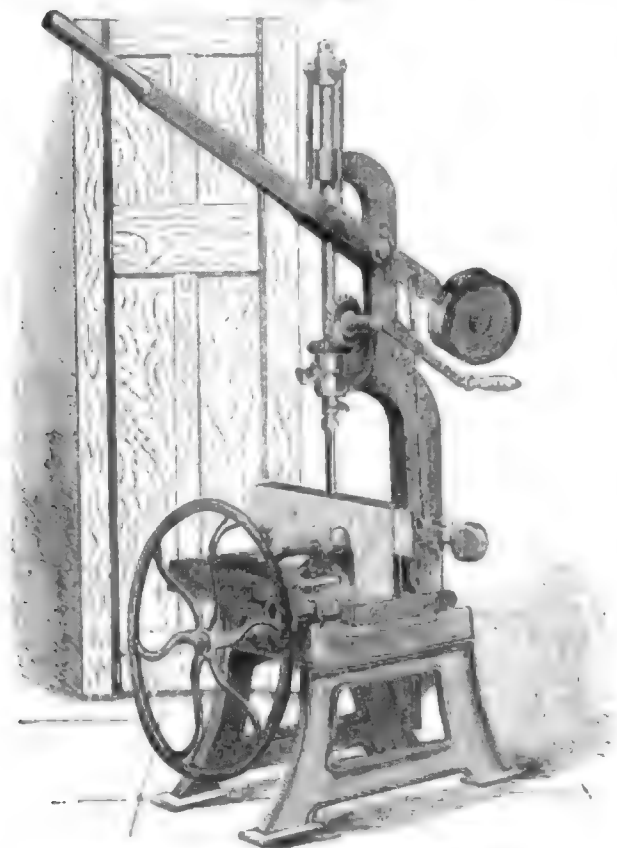
4. Moulding Machine.—This machine is designed for moulding, thickening, and squaring-up, and takes in wood up to 9 inches square. It is fitted with top and bottom cutters only, which are overhung at one side; the upper or moulding cutters first in order, the lower one, for the flat surface, following. Two pairs of pressure-rollers are applied,—the upper ones fluted,—and are loaded by means of one weight, as in the planing machine, though formerly they had two distinct weighted levers. The feed may be varied from 12 to 25 feet per minute, and is fitted with

disengaging gear. The wood is planed on one edge, on which it is guided by a straight-edge.

The table is levelled by means of mitre-gear and a screw (fig. 193).

5. Mortising, Tenoning, and Boring Machine.—This novel machine is arranged for the three distinct kinds of work—mortising, tenoning, and boring,

FIG. 194.



MORTISING, TENONING, AND BORING MACHINE, by Messrs. Powis, James, & Co.

and is worked by hand. It may be regulated for working hard or soft wood. For mortising, a thick chisel is employed, ground off on one

side, and fixed into a vertical spindle. It is brought down by means of a hand-lever and is driven into the wood, which is cramped to the table, to commence the mortise at the middle, whilst the table is traversed by a self-acting feed; this operation is repeated until one end of the mortise is reached. The chisel is then reversed or turned half round, by mitre-gear on the spindle, and cuts its way to the other end of the mortise. Thus, the mortise is cut square at both ends. The self-acting feed may be varied from $\frac{1}{16}$ inch to $\frac{1}{4}$ inch for each cut.

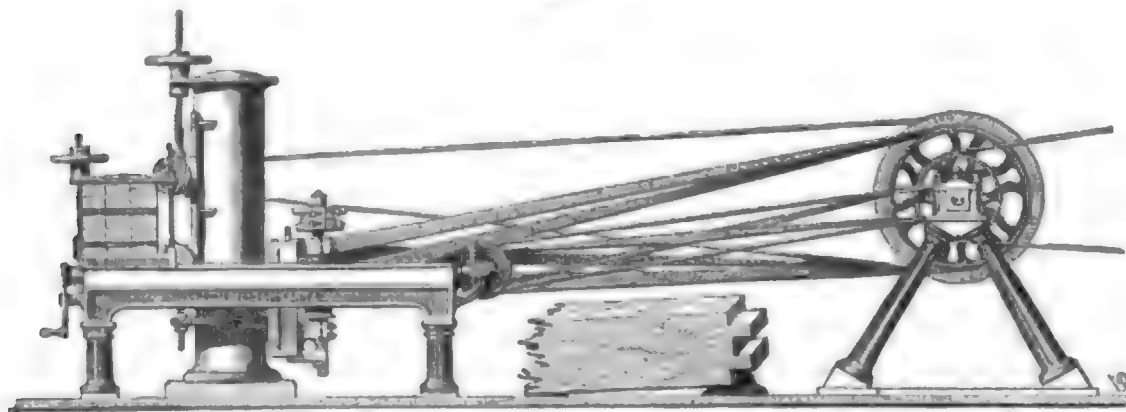
For tenoning, a duplicate cutter is used, each part like the letter L, advanced by vertical cuts on both sides of the tenon at once. To ensure exact work, the cutters move in a vertical dove-tail guide bolted to the bed of the machine. They may be set for any thickness of tenon.

For boring, the spindle is turned by means of the mitre-gear already mentioned. Thus, the mitre-gear is employed for a double purpose—to bore and to mortise.

This machine may be usefully applied for mortising and boring ships' blocks, with a spoon-bit, and a compound motion like that of a traversing slot-drill (fig. 194).

6. Double-Tenoning Machine.—This machine is adapted for working heavy framing, as that of railway carriages and waggon. It has two revolving cutters on horizontal spindles, for cutting out the extreme upper and lower sides of the tenons, with lances to mark out the shoulders and divide the fibres, and make a clean finish of the end grain. The intermediate space between the tenons is cut out by a cutter, or by a drunken saw, on a vertical spindle, towards which the work is traversed on a sliding table. The rate of feed is 24 inches per minute for hard wood. A coupling is applied to disconnect for reversing, for which a quick return at double speed is applied. The cutters are all adjustable to the

FIG. 195.



DOUBLE-TENONING MACHINE, by Messrs. Powis, James, & Co.

work to be done. Four waggon sole-bars may be put together on the table, and cut at one operation (fig. 195).

7. A horizontal steam-engine was exhibited, and will be noticed in connection with other steam-engines.

CHAPTER IV.

WOOD-WORKING MACHINES EXHIBITED BY
MESSRS. THOMAS ROBINSON AND SONS,
ROCHDALE.

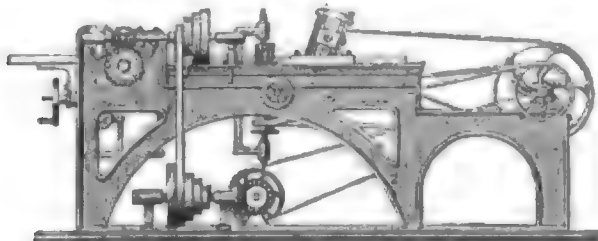
Messrs. Robinson & Sons exhibited a selection of machines for joiners' work, to enable a joiner and builder to prepare the whole of the work preparatory to wedging up and smoothing off, for sashes, doors, shutters, and similar framed work.

1. *Saw-Bench*.—This bench is made with a fixed table, and a rising and falling spindle for adjustment for rebating and grooving. The spindle carries a circular saw at one end and an auger at the other. The saw may be replaced by a circular cutter-block for tongueing or grooving. A separate stand is provided for the work to be bored by the auger. The parallel fence is made to cut at any angle, and may be removed for cross-cutting.

2. *Planing and Squaring Machine*.—This machine is for planing-up timber for the framing of sashes and other like framework, to remove warps, twists, or other irregularities on the surface of the timber. It receives timber of any size up to 15 inches square and 15 feet long. The cutter-disc revolves on a vertical spindle over the timber, and carries four cutters,—two gouges, and two chisels, alternating,—the gouges to clear the way for the chisels, and skim the surface. The timber is cramped on a travelling table, with which it is traversed under the cutter, upon a slide-bed.

3. *Moulding and Planing Machine*.—This machine takes in 9 inches by 3 inches; it has four cutter-blocks, to cut four sides at once. There are two pairs of feeding-rollers at the entrance of the machine, the first of which are fluted. They are all driven by means of spur-wheels geared together, and actuated by a worm-motion with four speeds. The under cutter levels the lower side, and is followed by the side cutters, and finally by the upper or

FIG. 106.



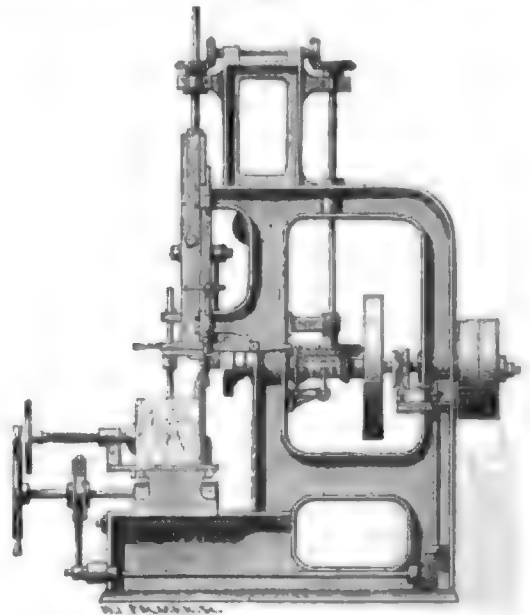
MOULDING AND PLANING MACHINE, by Messrs.
Robinson & Sons, Rochdale.

moulding cutters. The moulding cutters are made up in sections, to take different parts of the moulding. Two mouldings may be cut at once on a piece of double width, and parted by a cutter in the middle (fig. 196).

4. *Mortising Machine*.—This machine is worked by power, and operates by a reciprocating chisel, worked vertically. It cuts mortises from $\frac{1}{4}$ inch to 1 inch wide, and from $1\frac{1}{2}$ inch to 12 inches long. The chisel is fixed in a ram reciprocated by a connecting-rod from a revolving disc, like the motion of a slotting machine for iron, and it is worked by a self-acting feed-motion, in the first place, to dip into the timber at the middle of the mortise, and to cut deeper and deeper each stroke, clearing itself well, with a horizontal traversing feed, until the full depth has been reached, when the descending feed is thrown off by a stop-pin on the side of the ram, which knocks a clutch out of gear. The horizontal feed, worked by a cam and ratchet-motion, continues until the cutter arrives at the end of the mortise, when, by a movement of the reversing handle, a quick reversing motion is turned on, by which the chisel is lifted up out of contact with the work. It is then turned half round, into position for cutting towards the other end of the mortise, the descending feed is put into gear, and the traversing feed reversed, until the cut is completed; the piece of wood is then reversed for completing the mortise from the opposite side of the piece.

The descending feed is performed by means of a revolving screw with a fixed bearing within the ram, working through a nut in the stud by which the ram is driven. As the screw revolves, it descends through the nut, taking with it the ram and the chisel, and so giving the descending feed. By reversing the motion of

FIG. 107.



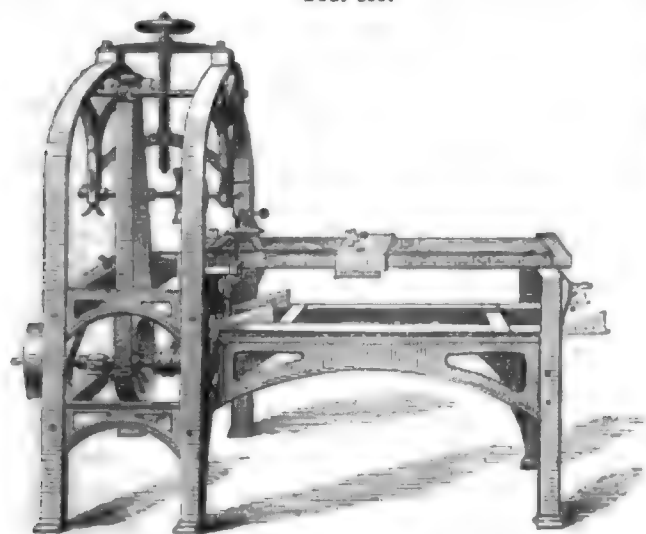
MORTISING MACHINE, by Messrs. Robinson & Sons.

the screw, it winds up the cutter from the piece. The screw is turned by means of a train of bevel-gear from the disc-shaft. The machine makes 120 strokes per minute, with a longitudinal feed of $\frac{1}{8}$ inch for each cut (fig. 197).

5. *Tenoning Machine*.—In the upper and lower cutter-blocks of this machine, which is

similarly arranged to the others that have been described, the cutters are twisted obliquely, and so screwed to the block. Lances are fixed to the rims of the blocks for sinking the shoulders of the tenon. A cutter-block fixed on the top of an upright spindle is mounted on a compound slide on the other side of the machine, for the

FIG. 199.



TENONING MACHINE, by Messrs. Robinson & Sons.

purpose of scribing sash-bars and stiles by means of a fly-cutter, or by substituting a thick saw on the cutter-spindle, to cut double tenons (fig. 198).

6. *Grinding Machine*.—This machine is for grinding and sharpening the cutters for the moulding machine. It consists of two sand-stones for grinding down the back of the cutter, and two Ayrshire stones for setting the fine edge without the use of oil-stones; they are fixed on a revolving shaft, formed with round hollows and round edges on their circumferences.

CHAPTER V.

WOOD-WORKING MACHINES EXHIBITED BY MESSRS.
GREENWOOD AND BATLEY, LEEDS.

These machines are of a special character, like those made by the same exhibitors for working in metals. (See page 180).

1. *Lock-Bedding Machine*.—The object of this machine, originally constructed in the United States, is to cut out the recess in a rifle-stock to receive the lock—a very delicate operation. The machine is one of a series of twenty-one for manufacturing gun-stocks, like those at the Royal Small-Arms Factory, Enfield. The cutting out of the recess for the lock is divided into five operations, for each of which a separate cutter is provided. The cutters are carried

each on a spindle, mounted on five separate slides in a rotating circular frame, and actuated by levers with universal joints, admitting of a vertical and a horizontal movement of the slides carrying the cutters. The table upon which the gun-stock and the “former” are placed, slides horizontally, at right angles to the horizontal motion of the cutter-slides. By compounding the motions, all the intricacies of the “former” may be traced to cut out the recess in the gun-stock. The cutter-spindles are driven at a very high speed, and are brought in succession over the work, to form the recess. The “former,” it may be explained, is an exact copy, in hardened steel, of the recess required to be cut in the gun-stock. The cutters are each governed by a “tracer” or point, of the same dimensions as the cutter to which it is connected, which is caused to traverse over every part of the surface of the former; thus, each recess is a facsimile of the original, and tens of thousands of recesses are cut perfectly alike.

By means of this machine one operator can bed 1,500 locks per week, or at least ten times as many as can be bedded by hand, with a degree of accuracy unattainable by the most expert hand-operator. One set of cutters will cut several thousands of recesses alike to the one-thousandth part of an inch; and there are ingenious means for maintaining the cutter at the exact size of the tracer, which is of course indispensable for maintaining the highest degree of accuracy.

2. *Blanshard Lathe*.—This lathe is designed for turning or forming wheel-spokes, on the principle of copying by a tracer from a former, and is so named after the inventor, who patented it many years ago in the United States. It is understood that the machine was originally invented in England, where it was, in a rude form, used for turning shoe-lasts. Within the last seven or eight years it has been brought into use in England, principally in consequence of its introduction at the Royal Carriage Department at Woolwich, for turning the spokes of gun-carriage and other wheels used in the military service. Two sets of lathe-headstocks are mounted side by side upon a travelling bed; in one of them a cast-iron former or model spoke is placed, in the other the piece of wood to be formed into a spoke. The spindles of both headstocks revolve slowly and simultaneously, at the same speed; and a circular tracer, held in contact with the former by a spring, and turning freely on its bearings, communicates its horizontal movements to the rotary cutter, of the same diameter, through the travelling bed, to which they are both attached. Thus, by a parallel motion, a spoke is formed by the cutters, an exact copy of the model. By a suitable application of wheels, right and left shaped pieces may be formed from one copy—

shoe-lasts, chair-legs, or other articles in pairs (fig. 199).

sometimes mischievous use of the adze is thus dispensed with (fig. 201).

FIG. 199.

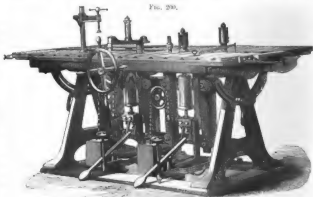


BLANCHARD LATHE, by Messrs. Greenwood & Batley, Leeds.

3. *Kinder's Shaping Machine*.—This machine contains two vertical spindles revolving in opposite directions. The "nose" of each spindle is screwed, and may be fitted with a variety of cutters. The head-stocks are capable of separate vertical adjustment. The frame of the table is mounted in trunnions, and may be canted either way. The top of the table may be traversed longitudinally, and is made with grooves across, which may be used for fixing work or appliances, or for transverse slides. By this means, under the guidance of a template fixed upon the work, the most intricate and various forms—in themselves oblique sections of regular or irregular figures—may be wrought with facility (fig. 200).

The wood from which the stave is to be cut is screwed into a press, of which the top and bottom plates are respectively of the form of the stave outside and inside. The press is fixed

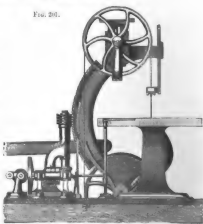
FIG. 200.



KINDER'S SHAPING MACHINE, by Messrs. Greenwood & Batley.

4. *Band-Saw*.—This is a band-saw peculiarly constructed, for cutting curvilinear shapes, as ribs for ships, and other heavy work of varying bevel, straight or curved. The table is stationary, and fixed in a level position, to carry the work securely, and the saw-frame is hung on a swivel, and may be set to any angle with the table. When ships' timbers or ribs are being cut for the bows of the vessel, they require to be cut to forms of double curvature,—to suit the bilge of the vessel, from the keel upwards; and in conjunction with that, they must be adapted to the tapering shape of the bow. The variations of curvature are marked in degrees upon the timbers at intervals along the curved line to be cut out on one face, the degrees expressing the successive angles of obliquity; and the saw being swivelled on a fulcrum having its centre at or near the surface, is set, by the aid of a graduated scale, successively to the necessary angles. The laborious and

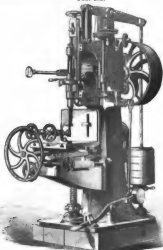
FIG. 201.



BAND-SAW, by Messrs. Greenwood & Batley.

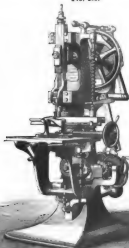
to a sliding carriage, with which it is moved forward between the saws, which form the exact joint-surface on each edge of the stave, to fit its fellow staves. The staves are previously cut out by a circular saw to the required curvature, thus entirely superseding the splitting-bill, the draw-knife, and the jointing plane used in ordinary coopering operations.

FIG. 202.



MORTISING MACHINE, by Messrs. Greenwood & Batley.

FIG. 203.



BOOT-PEGGING MACHINE, by Messrs. Greenwood & Batley.

6. *Mortising Machine*.—The chisel is fixed in a reciprocating ram, and is brought down by a

gradually increasing stroke, until the proper depth is reached and the required distance traversed, when it suddenly rises clear of the timber by the action of the foot of the operator. The chisel is then turned half round by a hand-lever, and the cutting process is repeated in the opposite direction, till the chisel arrives at the other end of the mortise. The table is provided with slides and trunnions to set the work for bevel-mortising (fig. 202).

7. *Boot-pegging Machines*.—These machines have already been described in connection with the other machines, by the exhibitors, for working in metal, page 181, and are here illustrated by the annexed figure, 203.

CHAPTER VI.

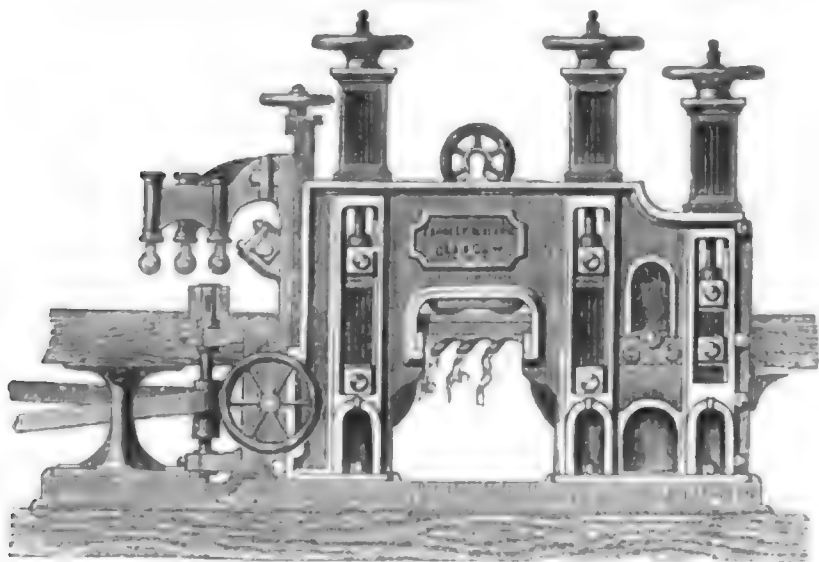
SUNDRY WOOD-WORKING MACHINES.

Messrs. Forrest & Barr, Glasgow, exhibited a *planing and moulding machine*, for planing, thickening, feathering, and grooving, or matching boards. A series of smooth friction-rollers, geared together, are provided for drawing the timber and passing it through the machine. The entering rollers gear together with long-toothed wheels, to allow for their separation and keep them in gear, with boards of extra thickness. A revolving cutter skims the boards preparatory to their being planed by the three stationary plane-irons which succeed it; followed by two side-cutters and a top cutter for thickening boards or to cut mouldings. The level of the upper friction-rollers is adjustable by means of screws, and the pressure is applied to them by means of springs. The machine works at the rate of 60 feet per minute for soft wood; for the hardest wood it is worked at the rate of from 16 to 18 feet per minute (fig. 204, page 224).

Messrs. J. McDowall & Sons, Johnstone, near Glasgow, exhibited a *saw bench*, with a circular saw on a rising and falling spindle, on a fixed table. Also a *planing and moulding machine*, with three pairs of smooth pressure-rollers geared together with spur and bevil wheels. Each roller is weighted by a pair of weighted levers, one at each end, making twelve independent weights.

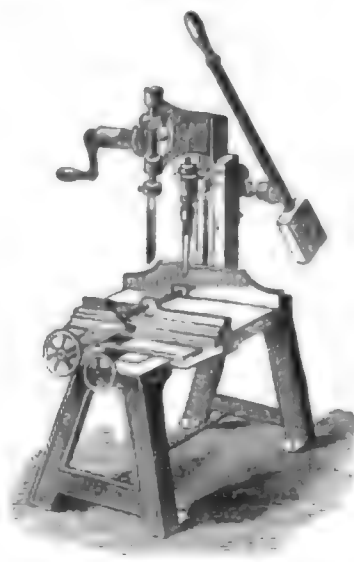
Messrs. J. & T. Young, Ayr, exhibited a *vertical saw-frame*, or *deal-frame*. It is capable of cutting two deals at once, 24 inches by 5½ inches thick, making 220 strokes per minute. The power is taken from a driving-shaft at the top of the machine by a connecting-rod attached to the bottom of the saw-frame; thus a long connecting-rod is advantageously obtained. The top and side rollers are adjusted by screws, aided by spiral springs, to steady the timber.

FIG. 204.



PLANING AND MOULDING MACHINE, by Messrs. Forrest & Barr, Glasgow.

FIG. 205.



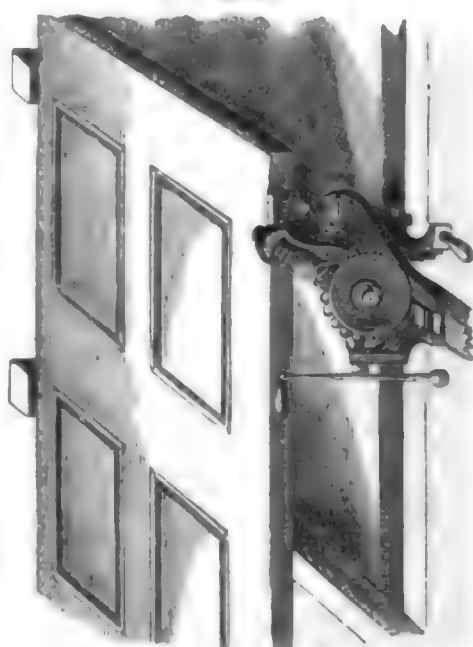
HAIGH'S MORTISING AND BORING MACHINE, by Mr. Wm. Bissell, Wolverhampton.

Mr. R. H. Thompson, Woolwich, exhibited a few simple and serviceable machines for rough ordinary work. 1. *Universal Joiner*, with an upright traversing spindle, on the principle of the radial drill, to be worked by hand or by power, and capable of doing a variety of work. The jib is hung upon a pivot at one side of a bench, which may be swept by the drill, and the motion is communicated to the spindle by an endless band passing over concentric pulleys at the pivot, the drill being free to radiate in any direction. Thus, by fitting a gouge or other bit to the spindle, a mortise may be cut; or, with cutter-blocks, straight or circular segments and mouldings. 2. *Tree-Feller*.—In this machine a couple of saws are let into and form portions of an endless reciprocating band between two pulleys. One pulley is stationed at one side of the tree to be felled; the other, on the opposite side of the tree, is capable of being shifted with its pivot in a circular segmental slide concentric with the stationary pulley. Power to work the saws by reciprocation horizontally is transmitted through the central or stationary pulley, and the feed is given by shifting the saw-frame towards and through the tree, radially upon the fixed pulley as a centre. When the near saw has cut half way through the tree the frame is shifted to the other side of the tree, to cut through the remaining half from the outside by the other saw. 3. *Horizontal Sawing Machine*, adapted for siding trees, or for cutting them into planks, &c., on the spot where they are felled. The felling-gear can be adapted to form part of the machine, and the whole can be easily put together.

Mr. Wm. Bissell, Wolverhampton, exhibited,—1. *Haigh's Mortising and Boring Machine*, in which the boring and the mortising chisels are placed in distinct frames, the boring chisel being turned by hand with a pair of mitre-wheels; and the mortising chisel fixed on a slide working vertically, upon which the power is delivered

through a hand-lever and an eccentric toothed wheel working into a rack on the back of the slide (fig. 205). 2. *A Flooring-Cramp*, suitable also as a bench-cramp and for doors and sashes. This cramp operates by means of an eccentric notched lever, to be turned against the joist, and so held until the pressure begins to be applied by turning the double handle, when the lever will gradually fix itself and hold the cramp firm. The greater the strain the more tightly the lever, by its eccentric action, will bind (fig. 206).

FIG. 206.



FLOORING-CRAMP, by Mr. Wm. Bissell.

3. *Lifting Jack*, 19 inches high, 66lb. weight, and said to be capable of lifting 4 tons.

Mr. W. Geeves, London, exhibited a *horizontal saw-frame*, or deal-frame, which is to the vertical deal-frame what a horizontal steam-engine is to a vertical one. Having a long foundation and a low centre of gravity, this saw-frame lies very steadily. It is simple in construction, but it has a short

connecting-rod; and every part is readily accessible, under the eye of the attendant. It is said that this machine may be driven at a greater speed, with less wear and tear, than upright saw-frames.

Messrs. Weston & Horner, London, exhibited a *mortising machine*, arranged to be worked by a treadle. Provision was made for oiling the chisel by self-action at every incision.

Mr. Joseph Lewis, London, exhibited a small machine for *boring and fret-cutting*. This machine is fitted with a table and treadle motion like that of a sewing-machine. For fret-cutting, a small saw is fixed in a rocking frame which works on a pivot at the back of the table, and holds the saw in tension by the two ends above and below the table. The reciprocating motion is

FIG. 237.



BORING AND FRET-CUTTING MACHINE, by Mr. Joseph Lewis, London.

derived from a small crank on the second shaft, working in a notch in the lower part of the rocking frame. For boring, a motion is taken off the second shaft by a band passing over guide pulleys to the spindle at the end of the rocking frame, which in that case is disengaged from the crank-motion (fig. 207).

Messrs. Cox & Son, London, exhibited a *machine for carving in wood*, applicable also for carving in stone or marble. It is founded on Jordan's patent, and is worked by steam power. It operates by copying a model, in duplicate or in triplicate, by means of the tracer

and one or two revolving cutters. But in place of the tracer and cutters being moved over the model and the work, as in other machines, they are stationary in a balanced frame, with freedom for vertical motion only, and they work on vertical spindles making from 5,000 to 7,000 revolutions per minute, whilst the model and the work are traversed under the tracer and cutters on a table capable of horizontal movement transversely and longitudinally. This machine was worked with efficiency; and it is said to be capable of roughing out four panels in four hours, which are finished by one man in a day, and which would take a man four days to carve by hand.

CHAPTER VII.

FOREIGN WOOD-WORKING MACHINES.

FRANCE.—M. Perin, Paris, exhibited at work a *band-saw*,—a machine with which his name is associated as the inventor, and which attracted great attention, by the precision and delicacy with which it was capable of cutting out, in the hands of a competent workman, the most intricate and involved scroll-work. The saw is bedded on leather, or india-rubber, laid upon the rims of the pulleys, without any other elastic medium. Tension-springs are considered by M. Perin to be unnecessary. A brake is set on by the same handle that throws off the belt, to stop the machine, which otherwise, after working at a high velocity, would continue to run for some time before arriving at a state of rest.

2. A *Traversing Mortising Machine*, analogous to the slot-drill, in which the mortise is formed by a traversing revolving cutter, working on a horizontal spindle. The cutter preferred for deep mortising consists of a double gouge, in section like an ogee, with cutting edges for penetration, and two longitudinal cutting edges for traversing. For cutting shallow mortises, a double cutter is preferred, keyed into a steel spindle, formed with two helical threads, winding about the spindle, for extracting the cuttings. The spindle is carried in a moveable frame, which is traversed on a sliding table, to give the feed for the traversing cut. A small driving pulley is fixed on the spindle, by which it is driven with a crossed belt from a fixed pulley overhead. The belt is sufficiently elastic to yield radially with the horizontal traverse of the spindle-frame. A square-ended cutter is carried by the same frame, to square the ends of the mortise.

MM. Bernier & Arbey, Paris, exhibited a few machines constructed with wooden framing. 1. A *Mortising Machine*, in which a revolving cutter, like an ordinary gouge, is used, with a web at the extremity, subtending the arc, like a segment of a circle, to give a cutting edge for

penetration. The gouge works horizontally, and readily clears itself of cuttings. The table which carries the work is traversed by rack and pinion. A double-ended square chisel, squared at both edges, with two inclined surfaces meeting at the middle, is used for squaring the ends of the mortises, without reversing the cutter as in the English machines. 2. *A Tenoning Machine*.—The cutter-spindle revolves at right angles to the tenon to be formed, and the cutters enter from the ends of the tenons, removing the wood in the direction of the grain, —a mode of action the reverse of that adopted in English machines, in which the cutters work across the grain. Three similarly formed cutters, for forming double tenons, are fixed by set-screws and separately adjustable, in sockets carried and likewise fixed by set-screws on the spindle. From the mode of their application, endwise, they are necessarily long and slender-looking to English eyes; and it may be noted, that the function of the ordinary oblique saw for cutting between the tenons is performed by an extended cutter. 3. *A Circular Saw*, which may be raised and lowered in the table at will. 4. *A Moulding Machine*.—The work is held steadily against the fence by springs bearing on a straight bar applied to the outer edge of the piece. The cutter-block is of cast iron, cylindrical, and made with sockets, nearly radial, to receive the cutters, which are fixed in place by set-screws, and may be set with great facility for cutting any moulding. 5. *A Lathe for forming Lasts, Wheel-spokes, &c.*—This machine is designed, like the Blanshard lathe, for forming irregular objects, from a model, by means of a tracer and similarly-formed revolving cutters. A single shaft carries as many cutters as there are duplicates required, guided by a tracer. The pieces of wood to be cut are suspended side by side between centres, at right angles to the cutter-shaft, and are revolved slowly and simultaneously, by being geared together and to the model. The cutters thus work vertically over the objects, and in the direction of the grain, and rise and fall with the tracer in a horizontal frame, which vibrates on bearings at the back. From a single model,—as of a last, for example,—right and left lasts can be turned.

MM. Varrall, Elwell, & Poulot, Paris, exhibited a *portable steam band-saw*, for heavy work, containing the boiler, the engines, and the machinery, on one cast-iron base. The boiler is upright, and the engine is fixed behind it, with two fly-wheels, turned on their rims for driving-belts. One of the fly-wheels is used in driving the intermediate pulleys for the band-saw, from which a motion is derived by gearing for the feed, which is performed by two pairs of rollers on vertical spindles, between which the work is passed. Only one of these pairs of rollers is driven by power. They are fluted to give the grip, and are adjustable to the required distance from the band-saw, for deter-

mining the thickness of the cut. The other pair of rollers, which are plain, are held taut against the work horizontally, by means of a weighted chain over a pulley, to steady the work, and also to give the necessary adhesion for the fluted rollers. The feed-motion, when not required, may be removed, and an ordinary guide-plate inserted. The band-pulleys are 2 feet 8 inches in diameter. The remaining fly-wheel may be employed for working a saw-bench.

SAXONY.—M. Zimmermann, Chemnitz, exhibited a *band-saw*, in which an arrangement is made for circular cutting, by swivelling the work horizontally on the table round a pivot fixed in it. 2. *A Vertical Reciprocating Saw*, for delicate work, in which the saw is moved by a crank, through an endless band. 3. *A Moulding Machine*, similar to that of Messrs. Robinson. 4. *A Planing Machine*. 5. *A Mortising Machine*, cutting with a revolving auger, traversed by hand; with a square cutter, to square the ends of the mortise. All of these machines are constructed with cast-iron framing.

CHAPTER VIII.

CONCLUSION.

The constructors of wood-working machinery are slowly adopting the style of the most advanced machine-tool makers, in massing their framing into the simplest forms and the fewest number of pieces, and placing each machine upon a single strong base-plate. In these respects, much of Messrs. Robinson's framing is in good style, and the material is well disposed. The sooner that the common architectural abortions in cast iron are abandoned, the better it will be for the founder and for the machine. The hollow or box system of framing, now successfully practised by the machine-tool makers, might be, with benefit, introduced in various ways in wood-working machinery, though, it may be added, there is not in this the same scope for the use of box-framework. A solitary instance of box-framing was supplied in the band-saw exhibited by Messrs. Powis, James, & Co.

Of the recent improvements in wood-working machinery, the general joiner of Messrs. Worssam & Co. comprises some excellent features; in particular, the fixed saw-spindle, and the rising and falling tables, independently adjustable, for the saw and for the auger; whereas, in others, the table is a fixture, and the spindle is shifted, —a motion which, besides deranging the connection of the band with the intermediate shaft, forbids the using of both the saw and the auger at the same time, unless at the same level.

The silent feed of Messrs. Worssam & Co., applied to their deal-frame, conveniently enables the attendant to adapt the feed exactly to the nature of the work, and without noise, in a manner which cannot be equalled by the ordinary ratchet and pall. In the employment of large rollers, in this frame they are enabled to act with a less number of them than with the usual small rollers, when smooth.

The portable band-saw of Messrs. Varrall, Elwell, & Poulot, is a novelty which will be found convenient for out-door work. It is a better machine for taking a single straight cut than the deal-frame; the continuous motion beats the reciprocating motion, and it requires less power to work it.

In planing-machines, the large smooth feed-rollers of Messrs. Worssam & Co., placed far apart, with the under-cutters between them, and with large spur driving-gear, contrast with the smaller fluted rollers, placed in close succession at the entrance of the machine, and the compact bevel gear, of Messrs. Powis, James, & Co. The wide spread of the rollers in the former machine is designed for drawing out, as well as to push in the timber, and to distribute the pressure, though they require not only larger spur-gear for driving them, but also a greater reduction of speed than in the latter. In the latter, the dressing and finishing undercuts are completed, and the sliding surface is formed, before any of the other cutters operate.

Thus, the timber may slide solidly through the machine for the succeeding operations, whilst the whole of the pressure for adhesion is available against the combined action of all the cutters. It appears, however, that Messrs. Powis, James, & Co. have, in their more recent constructions, enlarged the upper feed rollers, and extended the application of driving-gear to the lower ones. Messrs. Robinson show a very neat arrangement of spur-gear to drive all the rollers, these being, like Messrs. Powis & Co.'s, placed in proximity, and partially fluted. The weighting of the feed-rollers, usually effected by means of a number of weighted levers, is done simply and compactly in Messrs. Powis & Co.'s machine by one. In another machine, so many as twelve weighted levers are applied to three pairs of rollers. In another, springs are employed instead of weights, to load the rollers, though the elastic force must vary with the inequalities in the timber.

By means of the drawers employed by Messrs. Worssam & Co. for holding their under-cutters, these may be readily withdrawn for inspection, without disturbing the other parts of the machine.

The mortising machine of Messrs. Worssam & Co. is an ingenious application of the auger. It is in advance of the ordinary chisel-machine, and is adapted for the best class of work; but it requires very careful management. It is capable of cutting diagonal mortises.

SECTION III.

SUNDRY CUTTING TOOLS.

CHAPTER I.

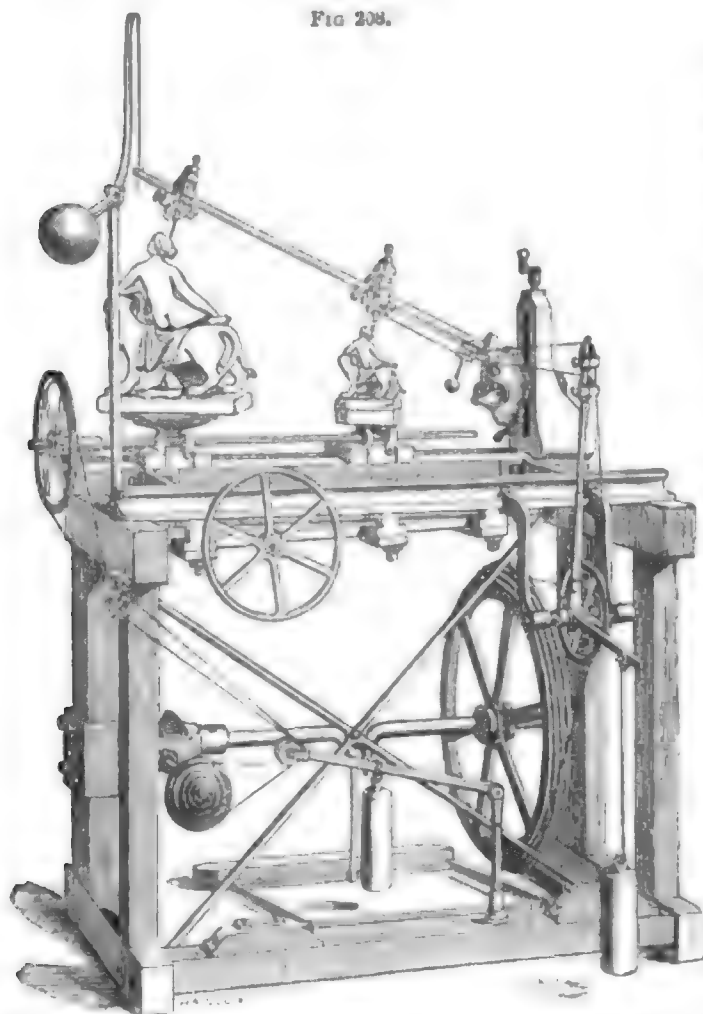
SCULPTURING MACHINES.

Sculpturing machines are designed for copying works of art in duplicate, by means similar to that of the former and the tracer, already described in the machines of Messrs. Greenwood & Batley, and Messrs. Cox & Son.

Messrs. Kennan & Sons, Dublin, exhibited a tastefully and compactly arranged *machine for copying sculptures* in ivory, wood, alabaster, &c., to any scale, either from relievos or rounds. In general appearance it is similar to an amateur's lathe. Motion is given by the foot, from which the cutter is driven at a high speed. The cutter and the "guide," or tracing point, are mounted on a triangular steel bar, working on a universal pivot at one end, attached to what may be called the fixed head of the lathe, and suspended freely at the other end by a balance-weight and cord over a pulley. The original and the block to be sculptured are fixed upon chucks mounted on two carriages,

which are adjusted in position on the bed of the machine, according to the required proportional dimensions, when, of course, the relative distances of the original and the block from the pivot of the bar must correspond with those of the tracer and the cutter. The chucks are turned simultaneously on their centres by means of two worms on one rod, turned by a hand-wheel from the end of the machine, and gearing into worm-wheels on the chuck-spindles, so that every part of a round object, accompanied by the block, may be brought before the tracer and the cutter respectively. The driving-band is kept at a uniform tension by being passed over straining-pulleys on a weighted lever at one side of the machine (fig. 208, page 228).

For carving long objects, in treating which the chucks are required to be traversed on the bed, to bring them within the scope of the tracer and the cutter, Mr. Charles Shaw, of Dublin, devised an ingenious arrangement of proportional slides for traversing the chucks in the ratio of their distances from the central pivot.



SCULPTURING MACHINE, by Messrs. Kennan & Sons, Dublin.

Mr. E. Smith, Sheffield, exhibited a *pointing and carving machine* for copying objects of sculpture. The model and the block are placed upon two revolving tables, turned in unison by a worm-shaft. With a dummy point, or tracer at the model, as a guide, a small drill or cutter, turned by a cord passing over pulleys carried by a swing-frame hung from above, operates upon the block. The point and the cutter are raised by a vertical screw in the frame. A ball-and-socket frame is applied for turning and under-cutting, or to descend upon a horizontal surface. For cutting basso-relievos, a parallel traverse on two guides is employed, with the screw. Six to eight points per minute may be made with this machine; and it is stated that ten or twelve times as much work can be done in the same time as by the old method, in which the point was shifted from the model to the block, to guide the cut.

CHAPTER II.

ENGRAVING MACHINES.

Two machines were exhibited for engraving rollers for calico-printing—one, a pantograph machine; the other, an electric engraving machine.

Messrs. J. Lockett, Sons, & Leake, Manchester, exhibited two *double-bar pantograph engraving machines*, for engraving rollers for calico-printing. One of these machines, on Rigby's patent, superseded the original double-bar pantograph machine with side bars, in which the pressure on the cutting diamonds was imposed by springs. Rigby's machine is furnished with top and bottom bars, and the pressure on the diamond levers is imposed by weights. An enlarged copy of the design to be engraved is prepared in outline, then transferred to a zinc plate, and engraved upon it, the engraving being facilitated by the enlargement of the scale. The engraved plate being placed upon the table of the machine, a tracer-point is conducted along the engraved lines, and works the diamond tracing-points in connection, so as to trace or scratch an equal number of diminished copies on the copper cylinder, which is covered with an etching ground. The pattern is bitten into the surface of the roller by immersion in a corrosive acid. The work being reduced from an accurately drawn and enlarged original, comes out so much the more perfectly in the reduction.

Whilst the machine just described works with a certain fixed ratio between the pattern engraving and the reduced copies of it on the rollers, the second machine, on Shield's patent, admits of various proportions for the enlarged pattern, even to a fractional part, ranging from two to ten times the size of the pattern as engraved on the copper:—adapting itself to the peculiarities of design, with economy in making sketches, and in cutting large designs on the zinc. As the sketch may be made to an approximate girth or circumference of rollers, the zinc may be prepared before the rollers are applied. But, besides the power of diminishing the design in any ratio, the proportions of the design itself may be varied, as the horizontal dimensions may be on a different scale from that of the vertical dimensions (fig. 209).

Mr. Garside, Manchester, exhibited an *electrograph engraving machine*, of which Messrs. York & Co., London, are the proprietors, for copying designs by engraving on copper or brass rollers, employed in printing woven fabrics and paperhangings. Designs may be multiplied, enlarged, or reduced; and the distinctive feature consists in the application of voltaic electricity in working the diamond points. Each point is provided with a small spiral spring, to press it against the cylinder, for etching, and, in addition, with a temporary magnet, of soft iron, by which it is withdrawn when the voltaic current is established. The magnets are connected in the usual manner with one pole of the battery.

For the purpose of forming the pattern, the design is, in the first place, engraved on an ac-

curately-turned tube of brass or other metal; and the engraved lines are, by a simple process, filled with a non-conducting material—gum or cement. The prepared pattern-tube revolves on insulated centres, and a tracer of platinum, in a suitable holder, being connected with the other pole of the battery, is arranged with its point in contact, with pressure against the tube whilst it revolves, and to traverse the whole length of the tube. Simultaneously, the diamond points traverse their own section of the roller to be engraved whilst it revolves. The current through the platinum tracer is interrupted as it passes over the insulating lines of the engraving, and is resumed when the tracer resumes contact with the metallic surface of the tube. At the same time the diamond points are released from their armatures and mark

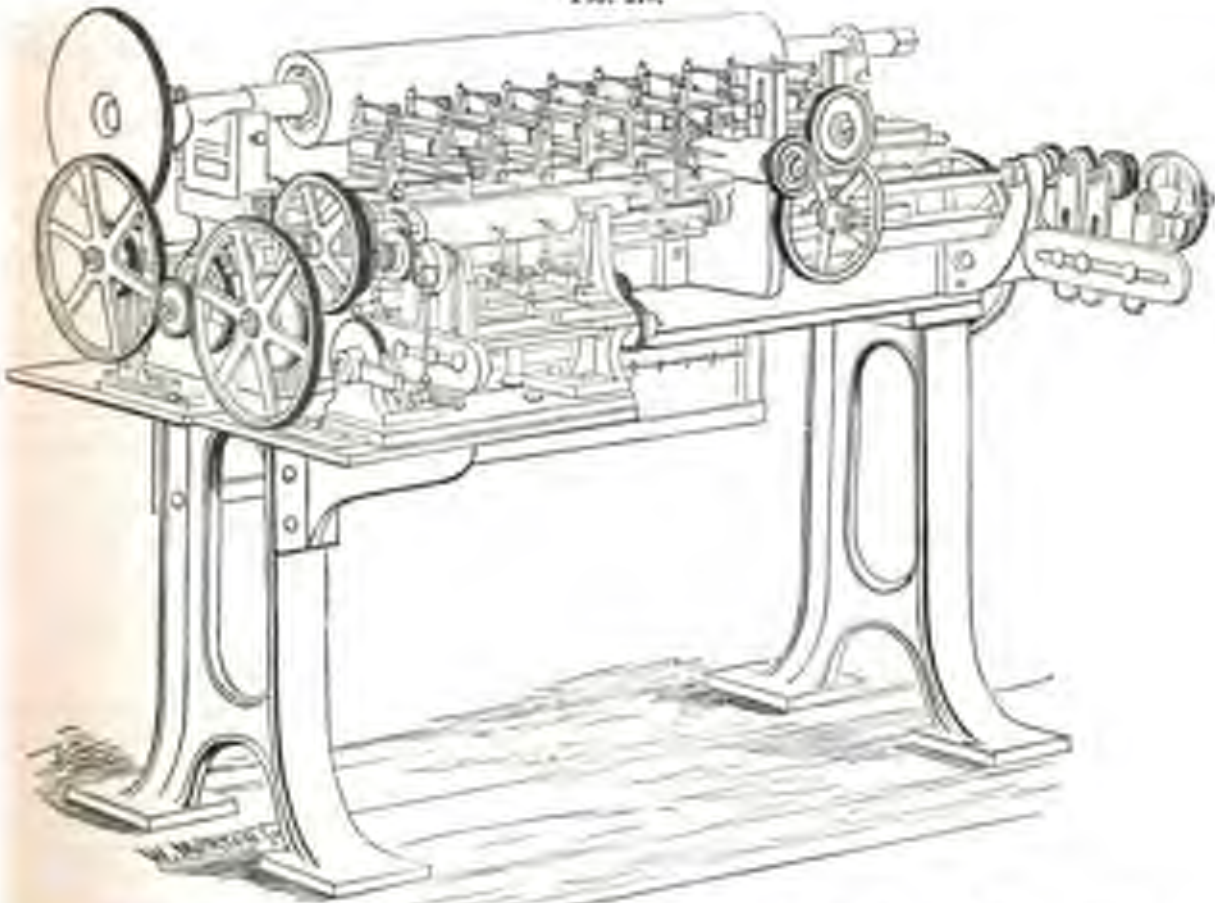
the cylinder; and they are then withdrawn from it by the armatures, and retained out of contact until the tracer crosses another insulated line of engraving. The combined result of these successive movements is, that the protecting varnish is scratched through, so as to form the copy of the pattern, and the roller is immersed in

FIG. 209.



DOUBLE-BAR PANTOGRAPH ENGRAVING MACHINE, by Messrs. Lockett, Sons, & Leake, Manchester.

FIG. 210.



PANTOGRAPH ENGRAVING MACHINE, by Mr. H. Garrideb, Manchester; and Messrs. York & Co., London.

a bath of strong acid to deepen the work. The proportional motions of the cylinder and

the engraved tube are directed by means of trains of wheelwork (fig. 210).

CHAPTER III.

CORK-CUTTING MACHINES.

Cork-cutting by machinery is yet to be accomplished as a commercial problem, though many attempts have been made to cope with the peculiar difficulties attendant upon the working of cork, and to compete with the cheap hand-labour employed in the business of cork-cutting. Cork is elastic, and it will not be cut, but tears, by the direct pressure of a knife; the cut must be a sliding or slicing cut. Cork, moreover, almost invariably contains silex or grit, which increases the difficulty of dealing with a yielding substance. Whereas, in stone, a separation may be accomplished by pressure or by concussion, in cork it cannot be accomplished by either; and no other but a sliding cut will separate cork with any thing approaching to a smooth surface. Another difficulty consists in the shape of the raw material: it is in sheets of very variable thickness, and it also varies much in quality in the same sheet; so that a machine set for cutting up a sheet into squares for rounding, cuts to waste a large quantity of material, either in the thicker or thinner part, and the saving of time by machine-cutting is more than counterbalanced by the loss in material. If, on the contrary, the machine be successively adjusted to suit the varying thickness of the sheet, there ceases to be any advantage in point of time over manual labour.

Many machines are therefore fed for rounding by blanks or squares prepared and cut by hand, the machines being for this purpose set to one size: if the square be at all deficient or not correctly centred, a flat is left on one side; and if the square be in excess, there is a waste of material. Whereas, by hand-cutting the squares are suitably rounded, the unsound and unsightly parts are removed, and the various sizes are adjusted afterwards; and thus the whole of the material is economised. If the machine, then, is to supersede hand-labour, it must pay for loss in material, and this is the result that has yet to be attained. Lastly, provision must be made for sharpening the cutting edge, which is a frequent source of delay.

Mr. Edward Conroy, Boston, U.S., exhibited a large *cork-cutting machine*, in the motions of which much ingenuity was displayed. The knife consists of a rapidly revolving disc, about 30 inches in diameter, on a vertical axis; the squares are fed from a hopper, and are seized by and suspended upon a couple of three-pronged centres, upon which they are rotated horizontally and held against the horizontal circular blade. They are thus quickly rounded, and then released to make room for successive squares. The whole of these motions are self-acting; the cutting disc being advanced and withdrawn alternately from side to side, so as to cut out a cork on each side alternately. It is stated that 200 gross of corks

can be cut per day by this machine,—a doubtful statement.

From the mode of application of the circular cutter to the rotating material to be cut, it would appear, that only a small portion of the cut at the centre can be a true cut; the remainder, near each end of the cork, subject to the retiring portions of the edge of the disc, being partly a tearing operation. There is also an apparent objection to the alternate removal of the large disc with its connections, from side to side, to act upon such a small object as a cork, which must be attended by complications of structure and absorption of power. When two objects are to be brought together it is better to move the smaller object and leave the larger one stationary. There is, moreover, the difficulty and delay of keeping in good and keen condition the edge of so large a revolving disc-blade.*

MM. Gärtner, Theyson, & Ede, Borgholzhausen, Minden, Prussia, exhibited a *cork-cutting machine*, in which the cork is formed by a revolving hollow cylindrical cutter like a wadding-punch, which descends vertically upon the material, and has a spring inside to eject the cork when cut. The exhibitors candidly acknowledge a loss of 25 per cent. in material; the loss is probably more than this, as, by the action of the cutter in descending, a considerable excess of material is required at the sides to prevent the weakest side being drawn in. Even where a completely cylindrical surface is cut, the ends frequently show the discoloured outside surface of the sheet. It was stated that the machine would cut six gross of corks without stopping for sharpening; but this must be taken as a most favourable estimate, as the smallest piece of grit would occasion a stoppage.

M. Gleuzer, Paris, exhibited a *cork-cutting machine*, which was the smallest, the simplest, and the best for the purpose. It indicated in its construction a good knowledge of the material to be dealt with. It did not cut the squares, but only rounded them, in a manner nearly approaching to the hand or sliding cut. This was effected with a knife about 18 inches long, which at every return stroke touched a little stock of grease to lubricate it just sufficiently to prevent its raw surface hugging the cork,—a tendency well understood by cork-cutters. By the same motion that forwards the knife on the cutting stroke, the cork is rotated on its axis

* Mr. Conroy's cork-cutting machine is thus heralded by Mr. J. E. Holmes, the Commissioner from the United States, in his official catalogue:—"A good cork-cutting machine, with the vast drinking propensities of mankind, is very desirable; and, but for the constant wish and desire of my life that the intoxicating beverages so common in the world were banished from existence, I suppose I should go into ecstasies over this invention. Surely, a machine that will reduce the expense of cutting from sixpence or eightpence per gross to twopence, will be considered a pecuniary success, and its value will be estimated accordingly, though death lurked in every bottle from which a cork should be withdrawn."

in such a manner that the corners of the square are first removed, and the body is then finished to a smooth round surface. This compound movement is not required for small corks. The machine cuts a cork to any conical form. There is no waste of material, and the ease and rapidity with which the knife can be sharpened, together with the small cost of renewing it, are points in favour of the machine.

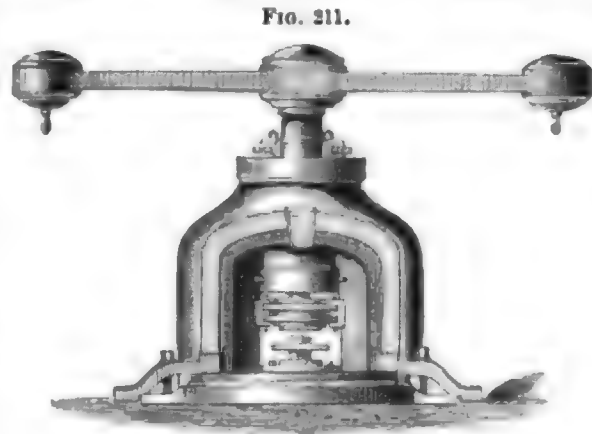
It is to be remarked that no cork-cutting machines were presented for exhibition in the English department.

CHAPTER IV.

COINING MACHINES.

Messrs. J. R. Pinches & Co., London, exhibited a *fly-press* for coining by hand, constructed for the exhibitors by Messrs. James Watt & Co., Soho. It was employed in the Process Court in striking medals in aluminium,—illustrating the adaptability of that new metal for the purpose. The screw is 6 inches in diameter, with three threads of $5\frac{1}{2}$ inches pitch. The double-swing lever is 9 feet long, and the weight of the lever and screw together is 13 cwt. The press altogether weighs $3\frac{1}{2}$ tons (fig. 211).

M. H. Uhlhorn, Düsseldorf, exhibited a self-acting *coining machine* at work, on a system extensively in use on the Continent. The chief novelty consists in the manner of distributing the blanks, and a self-acting motion for stopping



FLY-PRESS COINING MACHINE, by Messrs. J. R. Pinches & Co., London.

the machine when the blanks are exhausted, to prevent its being injured for want of blanks. For this purpose the layer-on is made to place the blank at a little distance from the coin under a small spring which takes hold of it. While the same layer-on runs back to bring another blank, a small pin descends upon the first and touches it through a hole bored in the spring, to ensure that there is one, and to keep it in its place till the layer-on closes one hand, takes it to the coin, and with another hand brings the second blank under the spring, and so on. If there are no more blanks, the pin, not finding one of them under the spring, continues its motion through the hole and stops the machine.

Messrs. J. F. Cail & Co., Paris, exhibited a *coining-press* capable of turning out from 40 to 45 five-franc pieces per minute.

SECTION IV.

MACHINES FOR MANUFACTURING AND WORKING IN PAPER.

THE machines employed in manufacturing and working in paper are designed, in the first place, to manufacture paper from linen rags and other fibrous material, to print or emboss upon paper, to fold sheets of paper, and to form bags, envelopes, or packages.

CHAPTER I.

PAPER-MAKING MACHINERY.

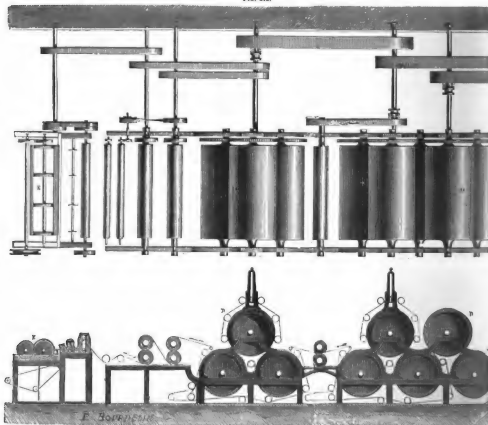
Two paper-making machines were exhibited in the English section, respectively by Messrs. Bryan Donkin & Co., London, and by Mr. George Bertram, Edinburgh. Two machines of Belgian manufacture were exhibited,—one by M. Laroche, of Brussels; and one by M. Dautreband, Huy.

Mr. Bertram's is an 80-inch machine, designed to turn out paper at 100 feet per minute. The knotter, fitted with Watson's cut plates, is pivoted at one end and lifted by a cam-shaft at the other end, making 180 revolutions per minute, with four cams to make 720 lifts per minute, the height of the lift being from $\frac{1}{8}$ to $\frac{1}{4}$ inch, and the fall being upon a piece of thick leather. The pulp is agitated by a revolving fan in the pulp-vat. The wire-frame contains 40 brass rollers, 2 inches in diameter, about $\frac{1}{4}$ inch clear, with wrought-iron journals, working in brass bearings cast in segments to hold ten rollers each, each segment being separately adjustable for local wear. The breast rolls to deliver the wire-cloth, and the carrying rolls below the shaker, are all suspended in the frame, and move parallel with it when shaken, to keep the wire cloth even and free from twisting strain. A save-all box is placed below the wire-frame to collect the water from the

pulp, whence it is pumped back to the pulp-vat. There are two vacuum-boxes, having perforated brass covers; one of them is fixed on, and moves with the wire frame; the other is fixed beyond the wire frame. The upper couch roll is of mahogany, the lower of copper, and both are felted. The pressure is applied through a weighted lever. There are two pairs of press-rolls, of which the upper rolls, 14 inches in diameter, are of cast iron ground to a true surface; the

lower ones are 12 inches in diameter, and being enclosed in felt and not easily got at, are covered with $\frac{3}{8}$ -inch brass. Steam is passed through the upper rolls. There are eight drying cylinders, $3\frac{1}{2}$ feet in diameter, heated by exhaust steam from the engine through the journals, with manholes and doors at one end. The paper is passed through a third pair of rolls for glazing the surface when partially dried, after it has been passed over five of the drying cylinders,

FIG. 212.



50-INCH PAPER-MAKING MACHINE, by Mr. George Bertram, Edinburgh. (A, the knoter or pulp-strainer, and

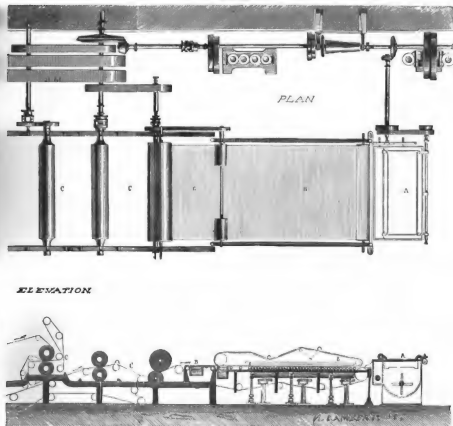
and before it is passed over the last three cylinders. The glazing rolls are naked and are heated by exhaust steam; they act by their own weight. From the drying cylinders the paper passes through two pairs of finishing cylinders or rolls, loaded by springs, and is finally reeled or drawn off through a pair of wooden rollers, driven by a friction-connected pulley,

with two leather-washers screwed up against the nave. The rollers being driven a little faster than the paper is delivered to them, the paper drags and is kept taut. The "single-web cutter" at the end of the machine, for cutting the paper into sheets, is on Crompton's principle, and consists of a continuously revolving knife fixed upon a series of rings on a central shaft,

and balanced by a counterweight. The knife is carried across the machine from side to side of the web, at a slight angle, so as to make a shear cut as it passes the "dead" or stationary knife. The speed of the rotary cutter-shaft is regulated for the various lengths of sheets required, by means of a double-cone expanding and collapsing belt-pulley, revolving more quickly and cutting off in quicker succession the shorter the sheet required (fig. 212).

Messrs. Donkin & Co.'s is a 90-inch machine for a maximum speed of production of 100 feet per minute. The pulp is introduced on a sand-catcher, 6 feet wide and 6 feet 6 inches long, with a cast-iron bed coated with zinc, and formed with a series of ridges, over which the pulp travels, and, on its way to the knottter, deposits the sand contained in the water in the hollows. The knottter or pulp-strainer has 21 square feet of area, with a total length of 800 feet of slits,

FIG. 213.



the pulp-vat; *x*, the wire-frame; *c*, the press-rolls; *b*, the drying cylinders; *a*, the single-web cutter.)

fully one-hundredth of an inch in width. It is agitated by a parallel up-and-down motion—500 to 600 times per minute—and the whole surface is uniformly agitated, and is all made available for straining the pulp. The wire-cloth is carried on copper rollers with brass pivots running in notches or bearings cut on the edges of two bars of iron. A self-acting wire-guide

is applied, to keep the wire-cloth in a straight course; it acts by shifting horizontally one end of the turn-over roller on which the cloth revolves, so as to alter the angle of the roller, and induce the cloth to keep the middle course. The couch rollers are of copper, with adjusting screws to regulate the pressure. There are three pairs of rolls or felt presses, and six drying

cylinders of cast iron, $\frac{3}{4}$ inch thick, 4 feet in diameter. There are two presses to smooth the surfaces of the paper, each consisting of three ground rolls. The cutting machine is fitted with a pair of circular cutters or shears, which revolve in contact to cut the paper longitudinally into strips, and with a long transverse movable knife, which reciprocates horizontally, and cuts off the paper against a dead knife. The length of paper to be cut off is regulated by a vibrating roller, which takes the paper with it, and draws or measures out the required length for each cut, the lengths being regulated by the extent of the vibration of the roller (figs. 213).

In the machine by Messrs. Laroche & Co., the paper is collected on reels, and is subsequently cut by slitting up in one operation the whole number of coils upon the reel. The rollers for carrying the wire cloth are small and far apart, their journals are of wrought iron, working in square notches, cut in the edge of the cast-iron frame. The vacuum-boxes have no perforated covers, the action takes place directly through the wire-cloth passing over them, the vacuum being produced by the fall of water through the discharge pipes, whilst the box is kept full of water.

In M. Dautreband's machine, the knotters are

FIG. 213.

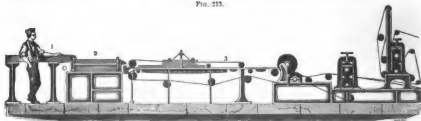
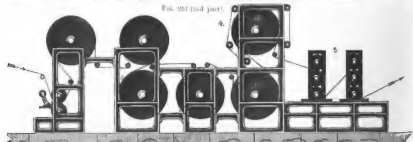
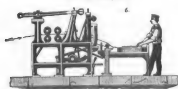


FIG. 213 (2nd part).



20-INCH PAPER-MAKING MACHINE, by Messrs. HUGH TUCKER & CO., LONDON. (1, the sand-catcher; 2, the pulp-strainer; 3, the wire-frame; 4, the drying-cylinders; 5, the press-rolls; 6, the cutting machine).

FIG. 213 (3rd part).



in sheet brass, the pulp is strained first downwards, then upwards, and the motion takes place upon pivots at one-third of the length of the knottor.

Remarks on the Paper-making Machines.—The sand-catcher applied by Messrs. Donkin is useful when there is sand in the pulp, which is diluted with about eighty times its weight of water. It is to be observed that the width of the wire

cloth is the principal element which determines the capabilities of a paper-making machine for rapidity of production. Mr. Bertram showed only one knottor in his machine of the kind most commonly used, and considered by most paper-makers to be the best; but, for the increased quantity of paper now turned out by such machines, and the greater width of paper-machines, it is found that two, or three, or even five such strainers may with benefit be applied to machines of the magnitude of the English machines exhibited. With a sufficient extent of straining surface the pulp is found to be much better cleared, and at less cost than with many of the other contrivances that have been designed for the purpose. With the radial shake of Mr. Bertram's knottor, quiet corners are provided for the collection of the knots which gradually settle there, and may be removed at pleasure; whilst, with the parallel shake of Messrs.

Donkin's machine, the knots settle equally over the surface, and require to be more frequently removed to prevent their stopping the straining slits.

The wire-frame or table is the most important part of the machine, as the paper in the state of pulp receives its first impression from the wire cloth. There, it is made uniform or otherwise in texture, even or uneven in thickness, and is closely or openly "put together." The other parts of the machine are employed only in finishing off what is in the first instance done upon the table. It is therefore apparent that the wire-table cannot be too nearly exact in construction or too nearly perfect in its movements. In all the best English mills, paper-making machines are driven at speeds of 100 feet per minute and upwards; so that if the endless web of wire cloth be, as in Mr. Bertram's machine, 33 feet long, it makes three complete revolutions per minute, and the shake which is given to the wire-frame for the purpose of weaving, as it were, or thoroughly uniting the fibres of the pulp together, must always be proportional to the speed of the wire. The tube-rolls for supporting the wire, in Mr. Bertram's 80-inch machine, are numerous and closely set, and are as large as those of Messrs. Donkin's 90-inch machine. In this respect, the Belgian machines are inferior to the English, as the tubes are neither so close nor so large; whereas, apart from the steadier bearing afforded to the cloth, the more numerous the points of contact of the wire cloth with the rolls, the greater is the facility for discharging the water from the pulp.

An important feature in the arrangement of the wire-frame of Mr. Bertram's machine, is that the tube-rolls, the breast-rolls, and all the other rolls connected with the wire-frame are slung or suspended entirely from the side bars of the frame; but, in the other machines, whilst the tube-rolls oscillate with the wire-frame, others of the rolls are centred on the fixed supporting standards, causing thereby an uneasy twisting and straining movement of the wire-cloth when shaken. This is one of the main considerations in manufacturing paper at a high speed, and if the wire-frame, with the wire, be not rigid and steady, not only is the paper imperfectly made, but the cloth, which is expensive, is quickly destroyed by the unequal twist to which it is subjected in the shaking process. So great is the difference in performance due to the arrangements for shaking the wire-frame, that whilst an 88-inch machine, with a properly constructed wire-frame, is capable of moving at the rate of 110 feet per minute, making 25 tons of paper per week, other machines with the wire-frame as commonly mounted cannot be worked at more than from 30 to 40 feet per minute, turning off from 8 to 10 tons of paper per week.

The next point relates to the means of expressing the water from the paper when it leaves the wire cloth. This is done by the first

and second press rolls. The brass jackets applied to the lower rolls in Mr. Bertram's machine, maintain the surfaces in proper condition for pressing the paper. Cast-iron surfaces become gradually decomposed and roughened under the action of the acids in the pulp, and are thus rendered unfit for the purpose of pressing the web equally throughout. Messrs. Donkin apply three pairs of press rolls instead of two pairs, as usual, with the view of reducing the work to be done by the drying cylinders, and to save fuel.

The interpolation of the smoothing rolls by Mr. Bertram amongst the drying cylinders, enables him to give a fine smooth surface to the paper whilst it is yet damp, by the simple weight of the upper cylinder, without having recourse to "heavy rolling" by the calender beyond the cylinders, after the paper has become completely dry. The spur-wheels for driving the drying cylinders are fixed by Mr. Bertram direct upon the ends of the cylinders within the frame, an arrangement which is favourable for producing steady and smooth work.

The cutting machinery employed by Mr. Bertram is adapted by its continuous revolving movement to work steadily and with precision at high speeds, even faster than the attendants can conveniently remove the sheets. The original inventor, Mr. Crompton, experienced great difficulty in getting the paper cut to any particular lengths, with the change-wheels he employed for regulating the size of the sheet. Mr. Bertram has overcome that difficulty by substituting an endless and seamless belt to drive the revolving crosscut knife, in combination with an expanding pulley and a few changes of ordinary pulleys on the end of the leading rolls. The collapsible reels exhibited by Messrs. Laroche & Co., for winding the paper delivered from the machine, are applied in the manner practised in England forty years ago, when the paper was reeled off in the wet state before drying cylinders were invented. The paper is reeled off until it attains a few inches in thickness, when it is cut through by means of saws or scythes into two or more sections, and removed and cut up into sheets. There is an obvious difficulty in obtaining, by this mode, sheets of equal length. It has been entirely abandoned in England for the cutting machine.

Sundry Pieces.—Mr. T. Marshall, London, exhibited a *revolving strainer* with six sides, which dip successively into a vat hung below the strainer. This is a costly arrangement, having a large proportion of inactive surface.

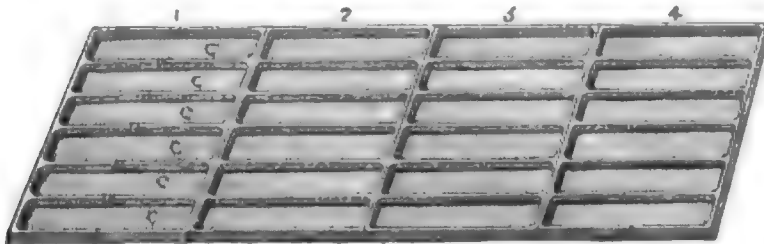
Mr. A. Siebe, London, exhibited a *cylindrical paper-knotting machine*, consisting of three cylindrical strainers or sieves placed in a pulp-chest, into which the pulp is poured from above, and in which it is agitated by fans, one in each strainer, which are put in rapid vibratory motion on their axes. By the centrifugal action thus excited, the pulp is forced laterally through the

sieves into the pulp-chest, leaving the knots to fall to the bottom of the sieves.

Messrs. Prentis & Gardner, Maidstone, exhibited a *strainer*, of a wedge form, depending from a rocking shaft into a vat, and rocked laterally. The lateral action strains the pulp through the sides of the strainer into the vat.

Mr. H. Watson, Newcastle-on-Tyne, exhibited samples of his *strainer-plates*, which have already been noticed. They are the most efficient for the purpose yet manufactured, particularly for high speeds of delivery. The

FIG. 214.



STRAINER-PLATES, by Mr. H. Watson, Newcastle-on-Tyne.

peculiarity of these plates consists in their being made with stiffening ribs, to prevent their springing when at work, and combining strength and lightness (fig. 214).

Messrs. G. Tidcombe & Son, Watford, exhibited a *paper-cutting machine*, which answers fairly for moderate speeds, but is perhaps too much complicated with cranks and back-throws to act correctly at high speeds.

Mr. J. Lamb, Newcastle-on-Tyne, exhibited a *paper-laying apparatus*, suitable only for low-speed machines.

Conclusion.—Though no great or radical change has been made in paper-making machinery since 1851, yet both the quality and quantity of production have been greatly increased. Whereas the machines of 1851 could turn off about five or six tons of paper per week, or in some cases ten tons per week, machines are now manufactured capable of turning out twenty to twenty-five tons per week. This increase of productive power is due to the much greater size of the machines now made—that is to say, they are made of greater width and with a greater number of drying cylinders, so that the paper may be dried at a greater speed of production. Recently-made machines, also, are made more firmly and compactly, the rollers and cylinders being placed more closely together to prevent the paper from vibrating in passing from one roller to another, and to afford greater facility in leading the paper through the machine. The Continental machines are narrow, and more like the English machines of 1851 than those of 1862. Paper-making machines in England are now made from 80 to 92 inches in width.

CHAPTER II.

TYPE-FOUNDING MACHINES.

Messrs. Johnson & Atkinson, London, exhibited a complete *type-casting and finishing apparatus*, in which the type-metal, kept melted in a cistern heated by a gas-burner, is forced by the usual small pump into the mould at the moment it comes into contact with the side of the cistern. The type cast at each stroke is pushed out of the mould, which is formed in three pieces, separated after each casting, and is carried by a traveller to a series of cutters, by which the shanks are taken off, the types rubbed and dressed, the bottom planed, and the nicks cut. This finishing process is a distinctive feature of the machine.

Messrs. R. Bealey & Co., London, exhibited a *type-casting machine*, in which the melted metal is held in a pan, with a well and piston. The piston is worked by a cam, through a crossbar attached to the piston-rod, with a side lever and connecting-rod. A "jobber" is fixed to the pan to prevent the return of the metal after it is pumped into the mould, which is fixed to the front of the machine, and is held against the pan whilst the type is being cast. When the type is cast, the mould is drawn back by means of a spiral spring, and is opened by means of a bar and rod, which are also used for delivering the matrix. The machine is driven by a lever and crank.

M. Haas, Bâle, exhibited a *type-casting machine*, in which the moving parts were very heavy.

The great advantage of those machines consists in the increased facility of production. One machine and one man will produce, in ten hours, 30,000 brevier types (or 60 lbs.), while by manual labour only 5,000 types (or 10 lbs.) can be cast in the same time. One casting machine, therefore, may be considered, on the average, as equal to six men employed on the same description of labour.

CHAPTER III.

TYPE-COMPOSING AND DISTRIBUTING MACHINES.

Type-composing and distributing machinery was successfully worked at the Exhibition, and was exhibited by Mr. W. H. Mitchell, London; by Young's Patent Type Composing and Distributing Machine Company, London; and by M. Delcambre, Paris.

M. Jorensen, of Copenhagen, exhibited, in 1855, a composing machine which justly attracted considerable attention. It was, how-

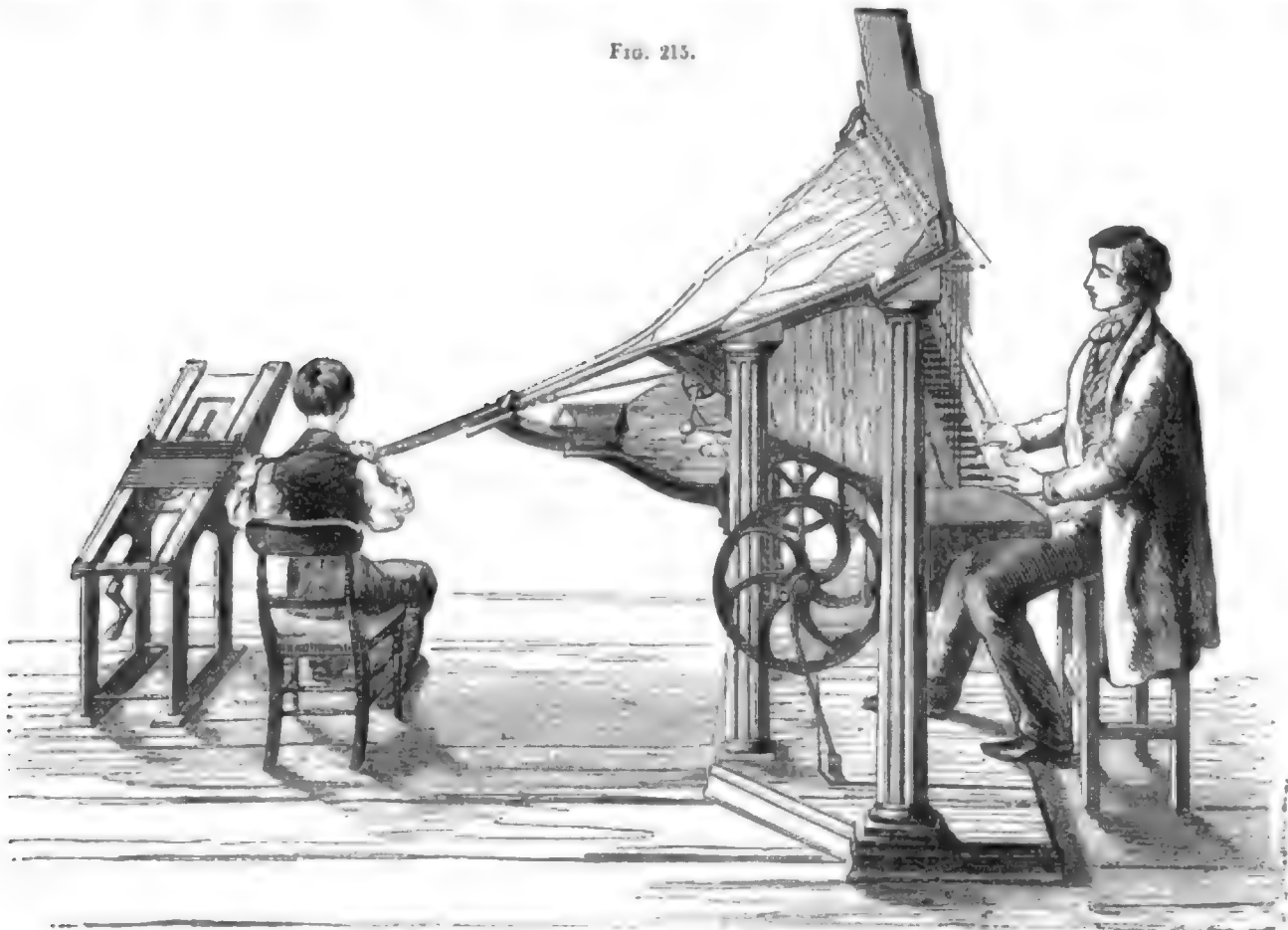
ever, a costly machine, and had a fault common to all machines in which the types are moved simply by the action of gravity upon an inclined plane: the velocity of travel is of course limited, as the letters, particularly the lighter ones, are subject to be retarded by very slight obstructions, and an *m* started after an *i* may occasionally arrive before it.

In Mr. Young's composing machine, and in M. Delcambre's, which is the same as Mr. Young's, separate compartments or "reservoirs" are provided for all the letters of a fount. Each reservoir is provided with a small lever, connected to one of a number of keys placed side by side, as on the keyboard of a pianoforte. When a key is struck by the compositor, a type is pushed out of the reservoir and is caused to slide down an inclined plane, and thence into a receiver, where it is set up side by side with other types by means of a beater. By this means it is said that from

12,000 to 15,000 types may be set up in one hour. The system of converging grooves arranged in an inclined plane by Mr. Young, is so planned that all the letters have the same, or nearly the same, distance to travel from the reservoirs to the receivers (fig. 215).

Mr. Mitchell avoids, in his compositor, the difficulty of the unequal drag on the inclined plane, already referred to, by supplying a means of carriage independent of gravity—namely, endless tapes circulating horizontally. The machine is, in shape, a right-angled triangle, placed horizontally, with a key-board at one of the sides, furnished with thirty-nine keys. Each key, when pressed, strikes out a type from one of an equal number of brass slides standing at an incline upon the machine, in a row nearly parallel with the key-board. The type thus liberated is conveyed upon a band, moving in a direction at right angles with the

FIG. 215.



TYPE-COMPOSING MACHINE, by Young's Patent Type Composing and Distributing Machine Company, London.

key-board to another band (forming the hypotenuse of the triangle), which carries it on to its destination. Arrived here, it is placed on end and pushed forward to make room for the next type, by means of a notched or serrated wheel called the "setting wheel." The words are thus put together with great rapidity in a long line of about thirty inches, which is afterwards divided by the compositor into lines of the required length.

The principle of the machine consists in the combination of bands, of such lengths and

such velocities as to enable the types, at different distances from the wheel, to reach it in the order in which the keys are struck.

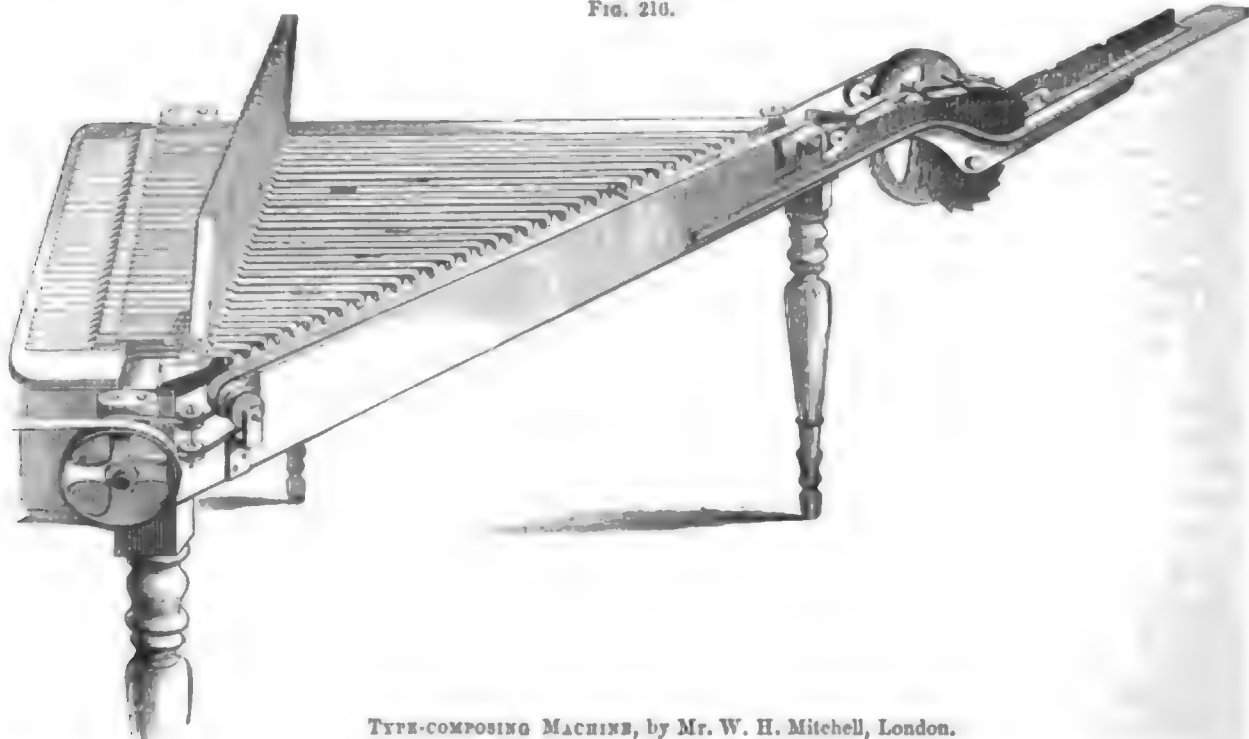
The compositor is capable of setting up types at the rate of six letters per second, or 21,600 per hour; but as the human fingers cannot attain to such rapidity, and allowance must be made for the operations of "justifying" and "correcting," the work of an average trained operator will probably not exceed 24,000 or 25,000 ems per day, which is about equal to the work of two men setting up type in the ordinary mode. As

each machine can employ two operators, the daily production is about 50,000 ens (fig. 216).

The distributor, exhibited by Mr. Mitchell, is a small machine of circular form. The lines of type to be distributed are placed successively in a long channel, in which they are pressed forward towards a vibrating metal "finger." By this finger each type is separated from the

line, pushed aside, and dropped on to a grooved brass wheel revolving horizontally. In the grooves of this wheel pins are placed, on which the types are hung by means of nicks, the ends of the types projecting below the under surface of the wheel at distances varying according to the position of the nicks. As each letter arrives over its receptacle, it is lifted off its pin and

FIG. 216.



TYPE-COMPOSING MACHINE, by Mr. W. H. Mitchell, London.

dropped into its place, being pushed a little forward to make way for the next arrival. When the line is filled in this way, it is removed by the boy to the compositor. The distributor is self-acting, and requires only the attention of

FIG. 217.



TYPE-DISTRIBUTING MACHINE, by Mr. W. H. Mitchell, London.

a boy. It distributes 8,000 letters per hour (fig. 217).

Both machines have been successfully used

with type ranging in size from great primer to brevier. They have been worked for several years in America, and have been recently introduced in England and Scotland. As compared with the present mode of type-setting, the following advantages are claimed for these machines:—1. An economy of labour varying from 30 to 50 per cent., according to the character of the work. 2. Greater facility in acquiring the printer's art, whilst it renders his occupation comparatively light and healthy. 3. Decrease in the wear of type, whilst a smaller quantity is sufficient for a given amount of work.

Mr. J. Coryton, London, exhibited his *type-composer*, of which the object is to enable the compositor to make as well as to set up the type for letter-press printing. This is done by stamping successively each letter upon the edge of a bar of soft type-metal. The mechanism for carrying out this system consists simply of a "matrix-box," and a fly or lever press similar to those used for embossing. The matrix-box (of hard copper) has on its under edge all the letters and symbols requisite for printing, struck into it from a steel die, the sides of the letters being parallel to the length of the bar. This bar is moved to and fro by the compositor (with his right hand) in a transverse slot at the lower end of the plunger of the press, the letters required to be stamped being each time brought into or near the middle of the plunger. The perfect

accuracy of adjusting the letter before stamping is insured by means of stops or pins within the plunger, which as the letter is brought down occupy recesses in the edge of the matrix-box. The plunger is worked with the compositor's left hand, and recovers itself by a spring after the blow has been given, and the letter made. As the plunger rises, the type-metal bar is moved forward by a spring kept in tension by a screw connected with the plunger, and is prevented moving further than the length of the letter formed, by coming in contact with the upper part of the orifice in a steel cutter, working on a pivot at right angles to the type-bar. When the word is complete, a smart action of the cutter severs it from the rest of the bar. The words thus severed are set up and adjusted in a grooved chase.

By this system it is considered that economy and dispatch are both promoted; so long as there is a supply of type-metal there will always be a supply of type, while to the rapidity of composition there is no limit but the dexterity of the operator in adjusting the matrix-box and bringing down the plunger of the press.

CHAPTER IV.

PRINTING PRESSES.

Printing presses, English and foreign, were exhibited in considerable numbers. The hand-presses, with the exception of Mr. Napier's, presented the stereotyped forms generally adopted by constructors, and patronized by the users, in which the figures of monstrous brutes are made to do duty as levers, and are likewise interwoven into the framing. It may be impossible to predicate where those monsters were originated; but they would puzzle a zoologist to classify them.

The report of the jury on Letter-press Printing contains the following useful summary of the progress of newspaper-printing:—Since 1851 two very remarkable changes have taken place in the machinery for newspaper-printing, but neither of these changes can be said to be represented in the present Exhibition. The first of these is the extensive introduction into this country of the horizontal four, six, eight, and ten-cylinder printing presses by Messrs. Hoe & Co., of New York; the second, the application of stereotyping to the rapid, safe, and economical production of newspapers having a large circulation. The printing presses of Messrs. Hoe & Co. had, like Applegath's vertical machines, been invented previous to 1851, and cannot therefore be regarded as novelties; but at that date only one had been introduced into Europe, and no sample or even model was exhibited in Hyde Park. There is a small model of the ten-cylinder press in this

Exhibition, but nothing else, to illustrate the mechanism by which the principal newspapers of the metropolis and great provincial towns are printed. The first presses sent by Messrs. Hoe & Co. to this country were for *Lloyd's Weekly Newspaper*, and were of the six-cylinder size. These were followed by two ten-cylinder machines, ordered by Mr. Walter for the *Times*, with the condition that they were to be made by an English machinist, who should be approved by him. The *Star* and the *Manchester Examiner* also ordered Hoe presses of English make, and the example thus set was speedily followed by the *Manchester Guardian*, the *Daily Telegraph*, the *Scotsman*, the *Illustrated London News*, and, in fact, all the leading papers in the United Kingdom. The experience, however, of the English-made machines had meanwhile (probably from the novelty of the manufacture) not been quite so satisfactory as that of those produced by Messrs. Hoe & Co.; and this gave a decided preference to the New York machines, of which not less than thirty-five have been imported since 1856. Mr. Walter still continues to use two of Applegath's eight-cylinder vertical machines in printing the *Times* and *Evening Mail*, but only as subsidiaries, the chief burden of the work falling on the two ten-cylinder Hoes made by Mr. Whitworth, and these are now said to perform admirably. They are driven at the rate of thirty-two revolutions per minute, which gives a printing rate of 19,200 per hour, or about 16,000, including stoppages. Much of the ingenuity exercised both in the Applegath and Hoe machines was directed to the chase, which had to hold securely upon its curved face the mass of movable type required to form a page. The complicated contrivances by which this was effected have now been entirely superseded by the use of stereotype plates; but before proceeding to describe the process by which these are obtained, it may be well to draw attention to some of the points which seem to have determined the preference now given to the Hoe presses over the Applegath. The course of the sheet in "laying on" at the Hoe machine is as direct as it can be made, short of printing from a continuous web; and the "taking off" is performed with great regularity by means of a wooden frame, which rises and falls with each impression of the printing cylinders. At the Applegath press, the direction of the sheet has to be changed from a perpendicular to a lateral motion, to correspond with the vertical position of the main drum. A taker-off is also required for each impression-cylinder, as well as a layer-on, thus considerably increasing the number of hands. The American machine also possesses a decided superiority in the arrangements for securing good register, though the ingenious finger-motion by which this result is obtained becomes objectionably rapid in the largest-sized presses. The comparison instituted between

these celebrated rival machines, and indeed all the foregoing details, have been introduced into this report less as bearing on subjects contained in the Exhibition than out of deference to the immense importance of the newspaper-printing machine in a country governed by public opinion. The same considerations render it incumbent on the reporters to point out, that excellent and surprising as are the results achieved by the Hoe and Applegath machines, they cannot be considered satisfactory while these machines themselves are so complicated, expensive, and liable to stoppages in working. No true mechanic can contrast the immense American ten-cylinder presses of the *Times* with the simple calico-printing machine without feeling that the latter furnishes the true type to which the mechanism for newspaper-printing should, as much as possible, approximate.

Of the stereotyping process, which has been referred to as the second great change effected in the art of newspaper-printing since 1851, there exists no example whatever in the Exhibition of 1862. Yet it is a change hardly inferior to that by which the late Mr. Walter applied steam-power to the printing press, and certainly equal to that by which the rotary press superseded the reciprocating action of the flat machine. It was commenced and has been elaborated to its present point by his son, the present Mr. Walter, at the *Times* office. He began his experiments, aided by an ingenious Italian founder named Dellagana, early in 1856, when, by means of papier-mâché matrices rapidly dried and placed in a mould, columns were cast in stereotype-metal, type-high, planed flat, and finished with sufficient speed to get up the duplicate of a form of four pages, which—when worked off on a spare flat machine—accelerated the speed at which the *Times* had previously been published by nearly 5,000 impressions per hour. The next step taken was to adapt these type-high columns to the Applegath presses, then worked by polygonal chases. That raised the previous 5,000 to 10,000 per hour; but though the publication of the *Times* was thus finished in much less time than before, it soon became clear that the process could be greatly simplified in its details, and greatly extended and improved in its application. Accordingly, on the introduction of Hoe's machines, instead of dealing with separate columns, the papier-mâché matrix was taken from the whole page at one operation by roller-presses constructed for the purpose. The matrix, rapidly dried on heating surfaces, was then accurately adjusted in a casting machine curved to the exact circumference of the main drum of the printing press, and fitted with a terra-cotta top to secure a casting as nearly as possible of uniform thickness. On pouring stereotype metal into this mould a curved plate was obtained, which, after undergoing a certain amount of trimming at two machines specially made for the purpose, could be taken to press

and set to work within twenty-five minutes from the time at which the process began. For all practical purposes the printing obtained from these plates was as good as that from pages of movable type. All the risk and inconvenience and wear and tear attending the imposition of these pages in curved chases, and placing them on the presses, and subjecting them to the destructive friction of the machining process, were at once obviated. The fount, instead of wearing out every two years, might last for twenty; the plates after doing their work for one day, could be melted down the next into a new impression; and (most important of all) the original type-page, safe itself from all chance of injury, could be made to yield any number of copies that might be required by the exigencies of the circulation, and which there were spare machines to work. Thus has it come about that the inner or news sheet of the *Times* is now printed every morning, stoppages included, at the rate of 42,000 impressions per hour; the two American machines yielding 16,000 each, and the one Applegath used 10,000. Another Applegath remains in reserve, to increase the production, if requisite, and to provide against casualties. Between three and five o'clock every morning there are cast and finished in the foundry of the *Times* office three complete sets of each page of the news sheet, i. e., a triplicate of the eight pages, or twenty-four pages in all; and it will be perceived that if three machines working simultaneously failed to meet the requirements of the circulation, a fourth could be at once added. Mr. Walter has applied steam-power to the operations of the foundry, which, though still capable of considerable improvement, are now accomplished with great ease and certainty of result. It is obvious that by the multiplication of stereotype plates and machines, there is practically no limit to the number of copies of a newspaper that might be printed within the time which the process now usually occupies.

It is noticeable that England and the United States are the only countries in which these machines are in use. In the French department it was stated that the uncertain nature of newspaper property in that country prevented the investment of capital in this direction.

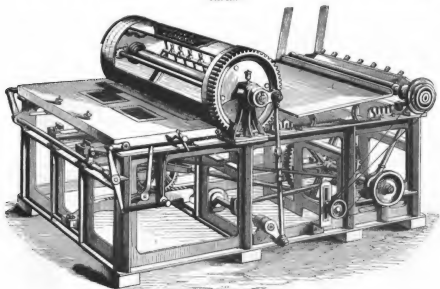
English Printing Machines.—Mr. David Napier, London, exhibited a large *platten printing press*, for fine work, worked by steam power, in which inking-rollers are, as in the hand-press, traversed four times over the inking-table for each impression, and the platten dwells for some time on the paper. The traverse of the table is derived from a skeleton worm, with an interval of rest at each end whilst the inking-rollers are in action. The downward pressure and the dwell of the platten are given by means of a combination of a crank and a knuckle-joint, in a manner unattainable by the instrumentality of the crank alone. The dwell

is a decidedly good feature for the production of really good work.

Mr. W. Conisbee, London, exhibited a "*Main*" single-cylinder printing machine, the principal feature of which is the method of connecting the cylinder to the type-surface by direct gearing, which is never out of contact. The cylinder is semi-rotative, or pendulous, making about three-fourths of a revolution only at each traverse of the type-surface, instead of an entire revolution, as in the case of the intermittent or stationary cylinders used by Messrs. Petter & Galpin and other exhibitors. The table is moved by means of a toothed wheel working between two racks, of which the lower is fixed to the frame, and the upper is attached to the table. The pinion is traversed backwards and forwards upon the fixed rack by a connecting-rod from a stud-wheel; and it is obvious from the nature of the motion, that the table has double the traverse of the pinion. This is a simple and durable motion. The bearings of the cylinder are eccentric, by

means of which the cylinder is lifted off the form in returning, after the sheet has been printed, the blanket on which would, if permitted to come in contact with the form, be inked while returning for the next sheet to be printed. The feed-table is placed horizontally, and of a height to enable a boy to place the white paper. It works in four V-shaped slides, and is connected by side levers and a connecting-rod with a cam on the main or stud-wheel shaft. To the front of the feed-table is mounted a shaft extending the full length of the table, and working in bearings fixed to it. The marks or lays are made adjustable to any length of sheet, or for two separate sheets, and they are also adjustable to any width of margin, which obviates the necessity for shifting the form after it has been fixed. The ink-duct is placed over the driving-shaft, to which is attached a vibrating composition-roller for the purpose of taking the ink from the duct-roller and depositing it on the ink-table; between the ink-duct and the cylinder are placed four diagonal distributing-rollers and three inking-

FIG. 219.



"*MAIN*" SINGLE-CYLINDER PRINTING MACHINE, by Mr. W. Conisbee, London.

rollers for inking the form, mounted on carriages fixed to the top of the side framing; the delivery-board is fixed over these rollers.

The sheet to be printed is placed up to the marks at the front of the feed-table, while the table is at its greatest distance from the cylinder, the sheet projecting beyond the front edge. The machine being turned, the feed-table advances towards the cylinder, depressing the

marks in its passage, and the sheet is taken at the moment it remains at rest. The grippers are opened while the cylinder is being reversed; and while the type-table is at the end of the traverse, all the centres of the main-shaft, crank, stud, and traverse-wheel are in line, the motion of the machine is reduced while turning the centre, as the crank-stud is at its dead point, and the sheet is taken by the grippers while exactly level with

R

the feed-table. After being printed it is brought up to the crown of the cylinder and taken off, with the printed side upwards, while the cylinder returns for the next sheet, by this time laid ready for it. By this means sheets may be fed more rapidly than can be accomplished by the stopping or intermittent cylinder, because no sheet can be placed on the latter until the opening of the cylinder is presented to the feed-table, as the sheet has to be pushed into the opening; while, as the grippers open while passing the front edge of the table, only very short grippers can be used, and the opening of the cylinder is so very limited that unless the paper be very flat they are apt to be missed altogether. Whereas, in the "Main," sheets are not missed, even when running at 12,000 to 13,000 per hour, though, in other cases, sheets are frequently missed, even when running at 900 to 1,000 per hour. This evil has no doubt to a certain extent been remedied, by the means for throwing the cylinder out of gear at will.

Uniformity of impression is insured in the "Main" by the method of direct connection by cut-gear, enabling the two surfaces to move always in unison. The gripper-motion is fixed to the cylinder-bearing: it does not wear out, as it has no action (fig. 218, page 241).

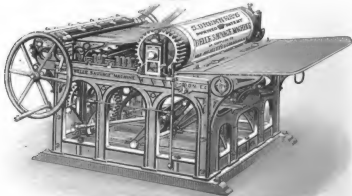
Messrs. Petter & Galpin, London, exhibited a "*Belle-Sauvage*" single-cylinder printing machine, in which the reciprocating motion of the

table is derived from the ends of a pair of rocking-levers on a vibrating shaft, actuated by a crank-motion from one end of the machine. The cylinder reciprocates in fixed bearings, and is driven by a rack on the table, gearing into a spur-wheel on the end of the cylinder, a portion of the spur being blank,—without teeth. The cylinder remains at rest whilst the change of sheets takes place; and it may be stopped, if necessary, without stopping the machine. This is a good machine for general printing work (fig. 219).

Messrs. Annable & Blench, London, exhibited a small *single-cylinder printing machine*, in which the table moves on live rollers, and is driven by a motion from a crank-pin on the end of an upright shaft, revolving horizontally, with a connecting-rod attached to a pin on one end of the table, guided by a roller working between two guide-bars below the table. By this motion the table is liable to wear sidewise, when the work is smudged to a greater or less extent.

Messrs. E. & W. Ullmer, London, exhibited a *single-cylinder machine*, in which the motion of the table is derived, as in the "Main" machine, from a spur-wheel traversed by a crank-motion between two racks, of which the lower rack is fixed to the frame and the upper one to the table. By this motion the traverse of the pinion is doubled in its transmission to the table.

FIG. 219.



"*BELLE-SAUVAGE*" SINGLE-CYLINDER PRINTING MACHINE, by Messrs. Petter & Galpin, London.

Mr. F. W. Gerish, London, exhibited a small *platten press*, in which the table is moved by an epicycloidal motion from two spur-wheels, one of which gears with and revolves within a stationary wheel with inside teeth, twice the diameter of the revolving wheel. The bed is connected to and is traversed by the inner or "planet" wheel, so as to have a traverse equal to twice

the diameter of that wheel. The bed is lifted up to the platten by a cam, to make the impression, the platten being stationary or fixed to the frame. A catch is provided at the end of the machine, to disengage the bed and leave it at rest until the workman has laid the sheet of paper, after which he disengages the pall. This machine is likely to absorb a good deal of power

to work it; besides which the motion is not sufficiently reduced by the gearing.

Mr. J. Ross, Leith, exhibited a *double-cylinder machine*, with a self-acting apparatus for setting-off sheets.

Mr. E. E. Colley, London, exhibited a working model of *Hoe's 10-feeder printing machine*, employed in printing the *Daily Telegraph*, of which it throws off 340 impressions per minute.

Mrs. Daniel Jones, Bradford-on-Avon, exhibited the "*Miniature Albion Printing Press*," for printing single pages, for private use or for merchants' offices. It is designed by the fair exhibitor chiefly for the use of literary ladies, for the circulation of new ideas. The work done by this miniature press in the Process Court was exceedingly good.

Mr. C. W. Harrison, London, exhibited an *electro-magnetic printing press*, in which the pressure is produced by turning over the armour-plate fixed to the form, into contact with the poles of an electro-magnet. The circuit is alternately broken and restored by hand. The work done was rough, and the labour was not light.

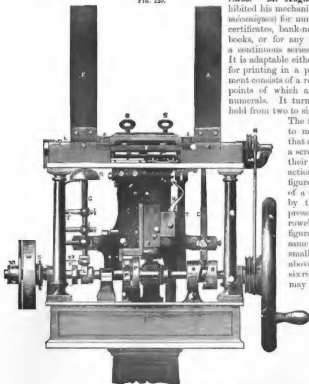
Foreign Printing Machines.—M. F. Normand, Paris, exhibited a model of a contrivance for imparting a regular motion to the table, which has been a desideratum in machines moved by rack and pinion. The radius of the pinion is varied in the inverse ratio of its angular speed, and the teeth of the rack are suitably adjusted in length to that variation.

M. Alauzet, Paris, exhibited a *cylinder-machine*, in which the table is moved by a motion from a slotted link, vibrating on one end, and reciprocated by a crank-pin in the slot, similarly to the ram of a shaping machine. A quick return is thus imparted to the table, and a proportional saving of time is effected. The propelling pinions and racks are made with oblique teeth, for the purpose of steadying the action.

M. Dutartre, Paris, exhibited a *printing machine* for working in two colours. It has two cylinders, with a double inking apparatus, one at each end of the frame, and two forms to be inked by two different colours; and thus the blank sheet is made to take the double impression at one stroke without being reversed.

Miscellaneous Printing and Stamping Apparatus.—M. Auguste Trouillet, Paris, exhibited his mechanical counters (*numéroteurs mécaniques*) for numbering coupons, railway certificates, bank-notes, for paging account books, or for any other purpose for which a continuous series of numbers is required. It is adaptable either for use in the hand or for printing in a press. The hand instrument consists of a rowel-formed circle, on the points of which are cut in steel the ten numerals. It turns on an axle which may hold from two to six or more of these rowels.

The figure or figures that are to move are left free; those that are stationary are fixed by a screw at the side, to prevent their being disturbed by the action of the others. The figure is changed by the action of a small lever that rises up by the wooden handle, the pressure of which turns the rowel so as to bring the next figure in its place, and at the same time inks itself from a small inking apparatus fixed above the figures. Thus, with six rowels, numbers 1 to 999,999 may be impressed, the first of the series appearing as 000,001. This instrument may also be used dry for stamping anything where colour is not needed, but only an impression, or with common marking-ink for stamping bales of goods or wooden



RAILWAY-TICKET PRINTING AND NUMBERING MACHINE, by Messrs. Waterlow & Sons, London.

packing-cases. For printing, eight rows with ten axes each may be used, fixed in a form, or rather on a plate, furnished with spaces to admit the movable types. If we suppose they number, as at first prepared, from 1 to 80, a horizontal handle moves all the necessary figures, and the next impression would give from 81 to 160. This process may be combined with the printing of labels requiring dates, such as those of the month and year. In such cases the necessary fixed type is prepared in the usual manner, and space is left for the numéroteurs to be inserted,

which are then operated on in the manner already described.

Mr. H. Palmer, London, exhibited a *paging machine*.

Messrs. Waterlow & Sons, London, exhibited a *railway-ticket printing and numbering machine*, in which the tickets are not only printed and numbered, but may also, if required, be perforated, striped, or double-coloured, at the rate of from 8,000 to 10,000 per hour. It is moved by steam, but may be worked by hand. The fixed type is placed in a frame, and the movable

FIG. 220.



NEWSPAPER-ADDRESSING MACHINE, by Messrs. Harrild & Sons, London.

figures or letters are engraved in steel or a brass rowel. By a vibrating action the frame is brought under a press to convey the impression to the paper, and the reverse movement brings the successive type to its place. The machine is self-inking (fig. 220, page 243).

Messrs. Harrild & Sons, London, exhibited a *newspaper-addressing machine*, which consists of a sliding groove of some length, on which is placed a galley containing as many of the required directions as it will hold, set up in type, and locked up. A treddle moves it along under a sort of parchment frisket or tympan, till a direction arrives just under the space cut in the frisket; the newspaper envelope is laid over the frisket, and the treddle brings down a pressure on it. The galley continues sliding on till all the directions have been impressed, when it is removed to make room for another (fig. 221).

Mr. Pearson Hill, London, exhibited a *post-office stamping machine*, used in the English post-offices.

Mr. G. Jarrett, London, exhibited small *hand-presses* for endorsing and stamping cheques,

sale-lists, &c., for embossing, and for marking linen. To avoid the objection to endorsement stamps, where fluid ink is used, from the inconvenience incident upon the drying or caking of

FIG. 221.

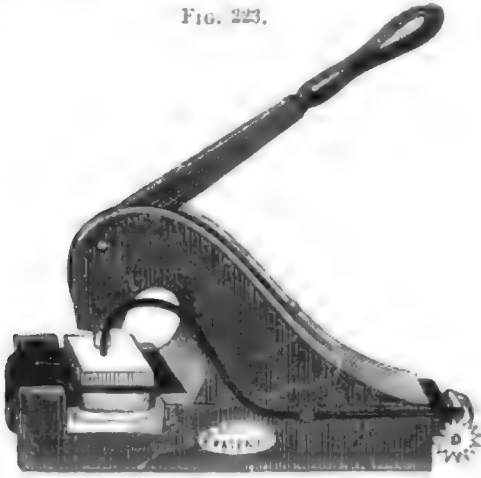


STAMPING-PRESS, by Mr. G. Jarrett, London.

the ink, Mr. Jarrett substitutes carbonic or other chemically prepared silk or other material, formed into endless bands, capable of giving more

than a thousand impressions before requiring to be changed. In one press (fig. 222), the die or type-holder is attached to the slide of the press by means of a taper, dovetailed key, so that it can be instantly removed for changing the dates, or for being replaced by another die. Another press (fig. 223), is more particularly

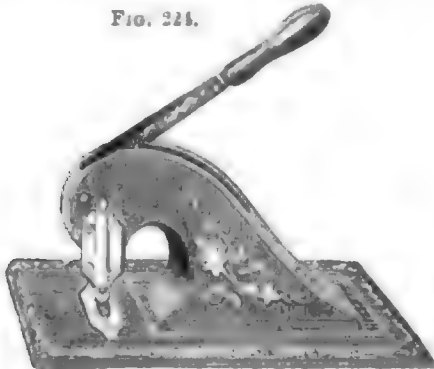
FIG. 223.



STAMPING PRESS, with movable dies, by Mr. G. Jarrett.

adapted for movable types, the dies or types being placed below with their face upwards, so as to be the more easily changed. The endless band, being double the length of the press, yields some thousands of impressions before it is exhausted. The embossing press (fig. 224) is

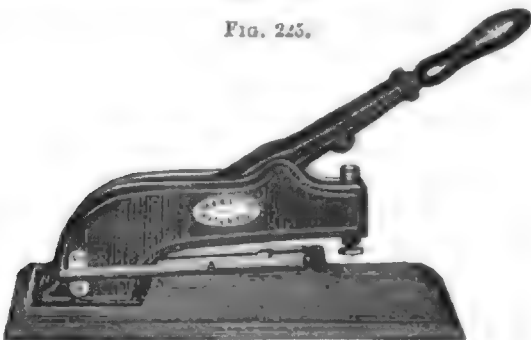
FIG. 224.



EMBOSSING PRESS, by Mr. G. Jarrett.

adapted for embossing crests, initials, &c. on paper. The slides to which the dies are attached are not taper, but are accurately planed. Each slide is made to fit tightly within a fixed iron

FIG. 225.



SELF-INKING PRESS, by Mr. G. Jarrett.

frame; it is depressed by means of a lever with a steel eccentric cam, and is raised by spiral

springs in brass boxes on each side of the head-stock. The dies are of steel, properly tempered, and the counterparts are of hardened copper. For marking linen, Mr. Jarrett exhibited a neat self-inking press (fig. 225), applicable also for endorsing purposes.

Lithographic Presses.—Several presses were exhibited for working copper and steel plates, lithographs, &c., both English and foreign, but in these there is no new principle involved. They are what is known as rolling presses, and the only improvements consist in a little more facility of working, increased power, and larger size.

CHAPTER V.

SUNDRY MACHINES FOR WORKING IN PAPER.

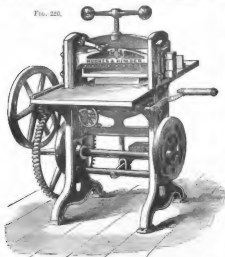
Messrs. D. & J. Greig, Edinburgh, exhibited, besides a selection of lithographic and other presses,—1. *A Paper-cutting Machine*, in which, with a continuous motion, the knife is caused to descend diagonally instead of vertically, as the diagonal or slicing movement of the knife makes a smoother and cleaner cut than the other. Messrs. Greig's first machines were made with a traversing motion of 5 inches; but their machines are now made with a 9-inch lateral traverse, in a descent of five or six inches. For this purpose the knife is controlled by a parallel motion capable of adjustment, which not only retains it in a horizontal position, but also causes it to move in a nearly straight diagonal direction; so that the full benefit of the slicing cut is obtained to the end of the stroke. This is an excellent machine. 2. *Copper Plates* for engravers, hammered by steam-power with a 56lb. tilt-hammer, having a long square piston with a spring on the top to increase the force of the blow, making 150 strokes per minute. The plate is finished by a hammer slightly rounded on the face. It is said that by this process the production is increased sixfold.

Messrs. Hughes & Kimber, London, exhibited, 1. *A Paper-cutting Machine*, in which the oblique or slicing cut is obtained by means of a radial link vibrating on a pivot on the frame, and connected to the knife-stock. The diagonal course being circular is of course of variable obliquity, being more nearly vertical at the commencement of the cut and sloping off towards the end of the cut (fig. 226, page 246). 2. *A Hydraulic Press* for bookbinders, by Tange Brothers. The table is 12½ inches by 17 inches long; the cylinder and the sole plate are in one piece; the ram is 3 inches in diameter, with a 1-inch plunger (fig. 227, page 246).

Mr. Balls Garrett, London, exhibited, with a number of printing presses, a *paper-cutting machine*, to work diagonally, like Mr. Ullmer's; or vertically, by withdrawing the diagonal bolt.

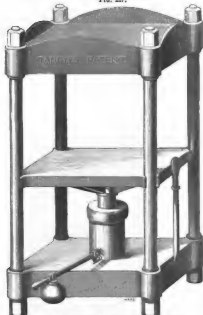
Mr. C. T. Youngman, London, exhibited two *machines for making paper bags*. One of them, the square-bag machine, makes complete bags from 2 oz. to 28 lb. capacity. It was worked

FIG. 226.



PAPER-CUTTING MACHINE, by Messrs. Hughes & Kimber, London.

FIG. 227.



TANGY'S HYDRAULIC PRESS, exhibited by Messrs. Hughes & Kimber, London.

by steam-power. The other, the conical-bag machine, was worked by hand, and makes from 1-oz. to 14-lb. bags. The bags are made from continuous webs of paper, cut off into lengths, folded, pasted, and delivered, by intermittent motions, to be afterwards pressed and dried. These machines make from 1,000 to 4,000 bags per hour, of various sizes.

Mr. S. E. Pettee, U.S., exhibited a *paper-bag machine* capable of making from 18,000 to 30,000 bags per hour, worked by hand. It works with continuous rotary movements, and makes the needful changes without the use of cams; hence the simplicity of the machine and the facility for working at high speeds. The knife which cuts off the lengths of paper revolves, and at each revolution cuts, or more properly tears, off the required length. It is an ingenious machine.

The Maschinen Bauanstalt, Frauenfeld, Switzerland, exhibited two *machines for folding and stitching printed sheets of paper ready for the bookbinder*. One of them prepares from 1,000 to 1,200 sheets per hour. The sheets are put singly by a boy under the points of the machine, in the same manner as with the printing machine. A knife moving up and down takes hold of the sheet lengthwise in the centre, draws it through a slit in the table, and the first fold is made. The knife returns instantly, and the sheet is taken by a second vertical knife, folding it at a right angle to the first fold. Before the third fold is made the stitching commences, two needles provided with hooks passing through the middle of the sheet at about an inch distant from each other, drawing through the cotton, which is unwound from a bobbin and cut to the required length. The sheet is then folded a third time, by a knife acting at a right angle with the second one, which takes hold of the middle of the sheet and pushes it between a pair of ribbed rollers, whence it passes directly to another pair of polished rollers, and remains glazed on the table. The machine works so correctly and truly that the sheets are folded and stitched with the utmost exactitude in the centre, and are so well pressed that the bookbinder can immediately begin wrapping. It is, moreover, so constructed as to fold the largest as well as the smallest sheets, and both the stitching and pressing apparatus, or each singly, may be detached by the loosening of a single screw. It can be worked by either steam or hand, a boy being sufficient for that purpose.

The other machine, exhibited by the same firm, lifts the sheets by means of an air-pump, which takes them one by one from off a pile under the horizontal folding-knife, thus enabling it to fold from 2,500 to 3,000 sheets per hour with the same precision as the first machine, without, however, making such perfect register, as no points are used in laying on, and it is therefore best adapted for the folding of news-

papers or other periodicals, where a perfect register is not absolutely required.

M. Devinck, Paris, exhibited an ingenious *packet-folding machine* which is intended for

wrapping up, sealing, and piling up cakes of chocolate. Its movements—thirty-one for each operation—are executed more regularly, in a cleaner way, and faster than workmen can do.

SECTION V.

MACHINES FOR WORKING IN STONE AND CLAY.

CHAPTER I.

MACHINES FOR WORKING IN STONE.

Mr. Neal, London, exhibited the *grinding-mill*, which has already been described for grinding flour, and is applicable for grinding colours, cement, or other stony materials. By varying the dressing of the stones, the mill is applicable to grinding chicory, drugs, chemicals, printers' ink, and such matters.

FIG. 228.



GRINDING AND LEVIGATING APPARATUS, by Mr. H. Goodall, Derby.

Mr. H. Goodall, Derby, exhibited a *grinding and levigating apparatus*, which consists of a

pestle and mortar, with a new differential motion for the pestle, whereby the range of the pestle is varied for every revolution, from the widest to the smallest range, and *vice versa*, thus doing the duty of scrapers. This variation is effected by shifting the centre of the crank which gives the fore-and-aft motion to one end of a lever, which, sliding longitudinally on its centre, in obedience to the action of the crank, at the same time vibrates laterally on the centre, and so communicates a resulting circular motion to

the pestle-shaft at the other end of the lever. The pestle may be weighted to any extent. The machine is adapted for grinding ginger, seeds, salts, cream of tartar, sugar, cocoa, &c., and for mixing or kneading lozenges, pill-masses, glaziers' putty, &c. (figs. 228, 229).

Mr. Thomas Carr, Birkenhead, exhibited a *double-acting composite mill*, for grinding and levigating or triturating chemicals, drugs, medicines, ointments, spices, herbs, &c., in place of the ordinary pestle-and-mortar. The mill resembles the ordinary edge-runner or mortar-mill; but the edge-runners, as well as the pan, are rotated each by separate driving-gear. The runners are turned in the same direction with the circumference of the pan, but at a much greater speed; so that, whilst they cease to be mere crushers, they become powerful grinders, to which the slow rotating pan acts as a continuous feeder. The runners are supported, like the upper millstones of a mill, so as to prevent their coming into immediate contact with the pan, or, when it is empty, resting on it; and the distance apart is exactly adjustable by a screw, as coarse or fine powder is wanted. Again, the pressure of the runners upon the material being ground is not dependent upon the weight of the runners, but is regulated by means of spring balances

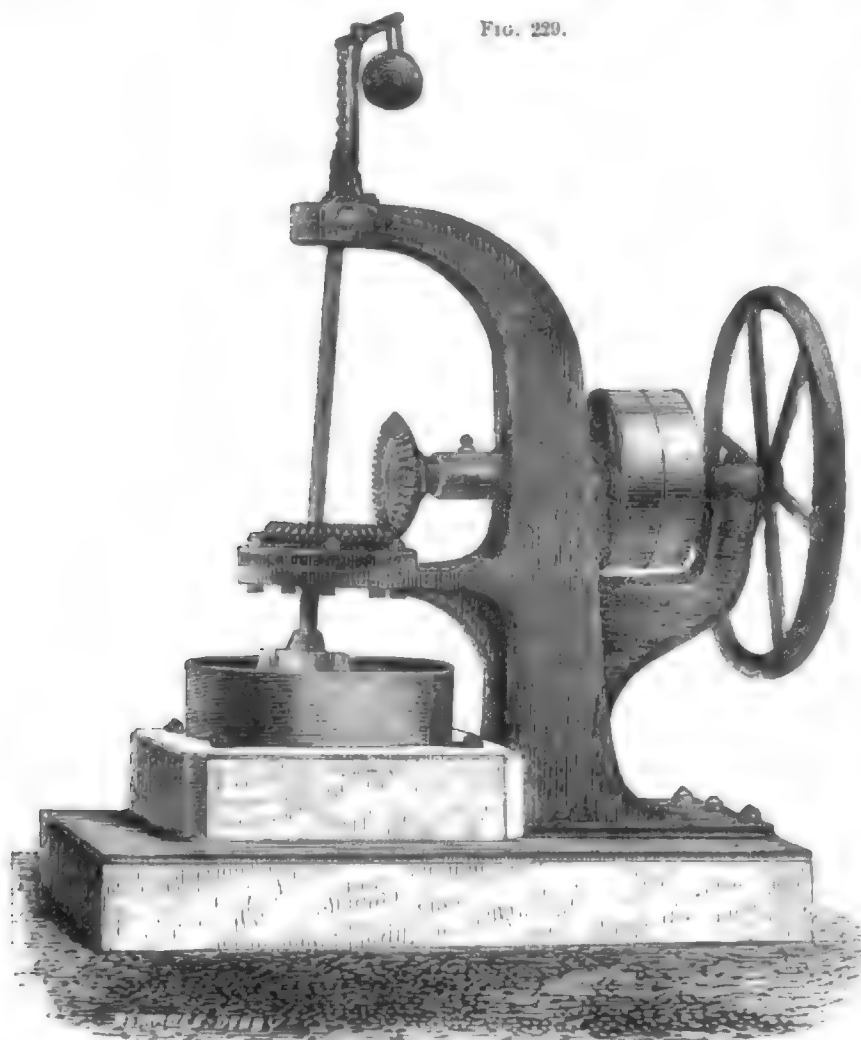


FIG. 230.

QUARTZ-CRUSHER, OR GRINDING AND LEVIGATING APPARATUS, by Mr. H. Goodall.

applied to the end of the lever-frames. In the small hand-mill, the pan can be readily tipped over and emptied, and replaced; and the pan, with the runners, are made of Wedgwood-ware. The mills are also constructed to be driven by steam-power; and the larger mills are capable of crushing the hardest minerals and ores, or of tempering clay and mortar, and kneading dough or putty (figs. 230, page 249).

Mr. Carr also exhibited a *disintegrator*, for breaking up and finely granulating cloggy materials, as conglomerated superphosphates, guano, sugar-scum; also for mixing purposes, as, for example, to convert brown sugars of various shades into one of a uniform shade. The smallest sizes are adapted to work by hand, for mixing light powdery materials, when a most perfect intermixture of the constituents is the chief desideratum. The larger sizes, to work by steam power, are for granulating purposes. They are driven by belts, instead of gearing. They consist of a series of four strong cylindrical iron cages, of various sizes, concentrically arranged one within another, on a horizontal axle, on which they are caused to revolve with great velocity in contrary directions to each other, by means of an open and a crossed belt, the alternate cages being so arranged to intersect one another, that while,

in reality, there are only two motions, there are relatively four—the first and third cages going to the right, the second and fourth to the left; one pair being in a piece with the hollow axle or boss on which the cross belt is placed, and the other pair keyed on to a solid shaft working within the hollow shaft, on the outer end of which is the pulley of the open strap. The crude material to be pulverised is shovelled, in its rough, lumpy condition, through a central opening into the innermost cage, and is instantly delivered in a radiating shower from every part of the periphery of the outermost one into an external casing or hood, in a state of the finest granulated powder, almost, if not quite, as regular and uniform in grain as gunpowder. The centrifugal action of the machine drives the material from the centre to the periphery of the outermost cage; but, before it can reach and escape from it, every grain of the material meets with and receives four distinct cutting blows, delivered with great

rapidity and violence, by the numerous but open set bars of the intersecting cages (156 in number) that it encounters on its way. The force of the blows is increased by the four reverse actions of the several cages. A stout knife is fixed to a pillar, cast in a piece with the carrying frame, in such a manner that its blade extends into the interior of the innermost cage, which instantly arrests and cuts such pieces as are otherwise too large to pass between its bars. Immediately this first cage is passed, any unfibrous substance, if less tenaciously pasty than dough, or not much tougher than oil-cake, or any brittle material, such as bone-ash, boiled bone from the size-makers, chemical crystals, coal, &c., is, in less than a second, thrashed, cut, and beaten to pieces, and the whole of it driven out with great force from the periphery in the condition of fine granulated powder. The powder can be made either finer or coarser, by increasing or diminishing the rotating speed (fig. 231, page 250).

Mr. H. T. Balfour, London, exhibited a *centrifugal crushing machine*, in which a revolving disc, mounted with wedges, within a close cast-iron case, throws the material to be crushed against the inner circumference of the case, which is formed with angular indentations, to receive and break it up.

M. F. L. Fauconnier, Paris, exhibited a *grinding mill*, having an annular trough, on which an edge-stone is moved by the rotation of a horizontal arm fixed to the revolving vertical shaft. Another arm moves a vertical scoop-wheel, which raises the pulverised materials, and throws them upon a conical sieve, ingeniously placed on the central opening of the annular trough, and shaken by a cam. By this contrivance the small particles pass through the sieve, and those which want more grinding return along its inclined and conical surface to the trough, and are ground again by the edge-stone in its passage. The scoop-wheel, made of thin iron plates, is brought round the annular trough by the vertical shaft, like the stone, but its revolution round its own axis is effected by a fixed cog-wheel placed horizontally and concentrically, which gears with the teeth on the circumference of the scoop-wheel. Thus it is designed that the materials should be kept under the stone just as long as is necessary, and that every particle should be of the required thickness.

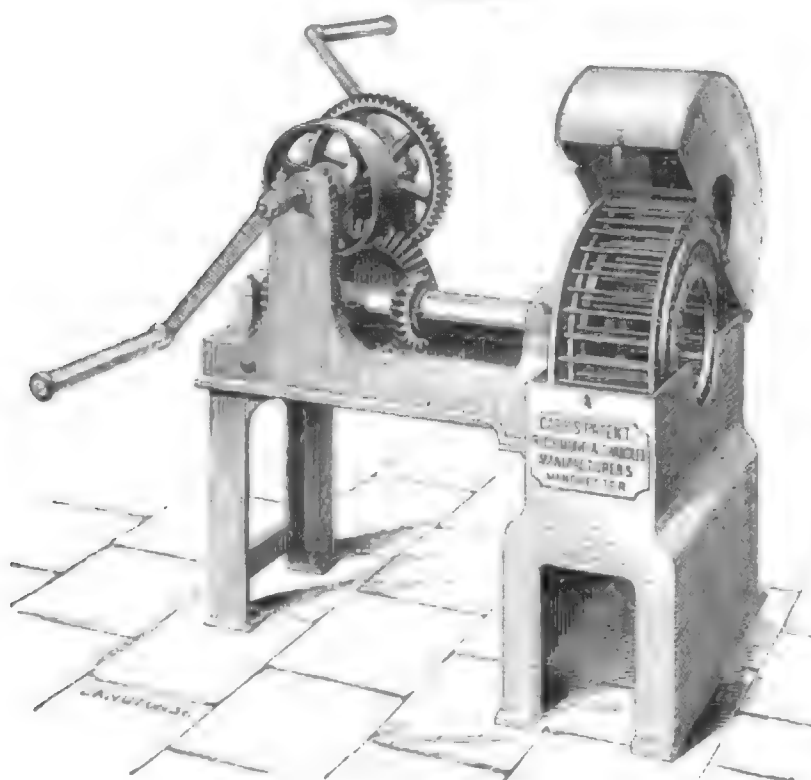
Messrs. Blake Brothers, Newhaven, U.S., exhibited an ingenious *stone-breaking machine*, to crush ores for smelting, or stones for road-making, railway-ballast, concrete, &c. The material to be broken is placed in a four-sided cast-iron receptacle, of taper form, open at top and bottom, the narrow end being below, and of the desired width or gauge of the broken pieces. The back of the receptacle is movable, and rocks between the sides upon a pivot at its lower edge, so as alternately to crush and break the pieces as it advances against the front, and to set them free as it is withdrawn, that they may fall through the bottom—such pieces, that is to say, as are sufficiently small to drop through. The pressure is applied to the rocking side through an effective combination of cranks, levers and knuckle-joints. The exhibitor has made the following tabular statement of the performance of three different sizes of the stone-breaker, in breaking stone of a compact formation, the jaws being set at $1\frac{1}{4}$ inches

FIGS. 230.



DOUBLE-ACTING COMPOSITE MILL FOR GRINDING AND LEVIGATING,
by Mr. Thomas Carr, Birkenhead. (Three views.)

FIG. 231.



DISINTEGRATOR, by Mr. Thomas Carr.

apart at the bottom, and the speed of the driving shaft 180 revolutions per minute :—

MACHINE.		PRODUCTION PER HOUR.	POWER REQUIRED.
Width of Jaws.	Maximum Distance between Jaws.		
Inches. 10	Inches. 7	Cubic yards. 4	Horse-power. 6
15	7	6	9
20	7	8	12

MM. Sommelier, Grandis, & Grattoni, Turin, exhibited a photograph of the machinery employed in perforating the rock, and now hard at work, in the construction of the railway tunnel through Mont Cenis, in the Alps. Several machines have been constantly at work since 1861 on the Italian side of the Alps. The wire machines of Bardonecchia perforated an average of eighty holes, 30 inches deep, in six hours, the rock being of variable quality. In homogeneous rocks, the same work can be done in $4\frac{1}{2}$ hours. During the year 1862, these wire machines made 45,751 holes, working 4,442 hours. The motive power is supplied from an air-compressing apparatus, by which, with a waterfall of upwards of 80 feet, 40 cubic feet of air is compressed into a sixth of its bulk. The compressed air is transmitted from the outside, and, after having operated, it is discharged, and it escapes to the floor of the tunnel, replacing and expelling the vitiated air; it also, in expanding absorbs the heat, and keeps the ventilation good and cool. During 1862, the consumption of

compressed air averaged 144,000 cubic feet per day, for motive power and ventilation.

CHAPTER II.

VICTORIAN QUARTZ-CRUSHING MACHINE.

The Commissioners of the Victorian Exhibition exhibited a *twelve-stamper battery* for crushing quartz, on a scale of half the full size, with ripple tables, amalgamating apparatus, and other appliances complete. It was an exact copy of the machinery used at the Port Philip Gold-mining Company's works, Clunes. This model battery is adequate to crush 70 tons of quartz per week. The following useful information on the performance of quartz-crushing machinery is derived from

the Catalogue of the Victorian Exhibition :—

"In working a quartz vein, a shaft is either sunk on the crown of the hill where the vein is found, or the reef is penetrated by an adit; and as the dip of the reef is commonly at a high angle, lateral excavations are made from the shaft or adit at various levels, from which the auriferous rock is excavated. The quartz brought to the surface is broken into pieces, and passed through inclined spouts to the stampers, which resemble the ordinary stamps used in other countries for dressing ores. They weigh about 7 cwt. each, and one stamp strikes about sixty blows per minute. A 10-horse-power engine will give motion to eight stamps. The crushed quartz is carried by water over copper ripples, where the gold is brought in contact with mercury. Once a week, or oftener, the ripples are cleared out and the amalgam retorted. Much dissatisfaction is felt by the miner as to the inefficiency of the means used at present to separate the gold from the quartz. When the latter is largely impregnated with iron pyrites and other sulphides, the amalgamation is incomplete, and much gold is supposed to be lost. Various experiments have been made, and numerous patents taken out for improved processes, hitherto without much effect on quartz mining; for it is now admitted by experienced miners that the machinery should be erected on a much larger scale, and that the ordinary process would be satisfactory if, instead of small engines of 20, 30, or 40-horse power, they could employ machinery of 200, 300, or 500-horse power for crushing purposes."

It appears from the reports of mining sur-

veyors in Victoria, that 86,594 tons 16 cwt. of quartz have yielded on the average 18 dwt. 22 gra. of gold per ton of quartz. In the Report of the Board of Science for the year 1860, it is stated that 39,034 tons of quartz produced 1 oz. 4 dwt. 8·41 gra. per ton. These results have been obtained by means of appliances which are known to be imperfect, and none of the operations have been pursued on a scale which would in Europe be considered large. Very few of the engines exceed 90-horse power, and the total amount of quartz which they are capable of crushing is inconsiderable. An engine of 18-horse power, driving sixteen stampers, each weighing about 6 cwt., and giving about sixty blows per minute, will crush about 150 tons of quartz per week; and it is estimated that an average of 1-horse power is required to drive a stamper, and that one stamper will not crush efficiently much more than 9 tons of quartz per week. When the cost of the crushing was about £4 per ton, very few of the veins could be worked with profit. Now, the cost of crushing and amalgamating is very low indeed,—generally less than £1 per ton; and a low yield was found to pay the quartz miner even better than a high yield when the cost of raising and crushing the quartz was so expensive. Even so little as 4 dwt. of gold per ton will remunerate the miner in some localities.

The mode of extracting the gold from the quartz differs in the details in many respects. Mr. G. W. Hart, the mining surveyor of Sandhurst, says:—"The stamper, in almost every engine, falls from sixty to sixty-five times per minute. The usual weight of the stamp is 5 cwt. The proportion of gold that one pound weight of mercury will take up depends on the size of the particles of gold; that is, after all the superabundant mercury is squeezed out through chamois-leather. If the gold be about as coarse as coarse gunpowder, one pound weight of mercury will amalgamate with one pound of gold; but should the gold be finer, it will take more mercury: therefore the coarser the grain of the gold, the less mercury it takes. The quantity of mercury placed in a machine at one time depends on the construction of the machinery. Generally, 180 lb. of mercury are required to charge the ripple boxes of a four-stamp engine or battery. It is usual to clear out the boxes, &c., once every fortnight; but most persons clear out the beds under the stamps once every week, as the crushed material, especially when in contact with mercury, becomes so hard through the constant pounding of the stamps, that a pick is often required to break it up."

Mr. Thomas Lawrence Brown, a mining surveyor of experience in the Castlemaine district, gives the following general description of the mode of extracting gold from quartz:—"To extract the gold from the hard quartz rock, the

matrix must be reduced to fine powder; and to effect this, the old Cornish stamps continue to be the most efficient and economical method. The best description of stamps are square or rectangular, cast of the best—that is, the hardest—white iron, with wrought-iron shanks, weighing from 5 to 7 cwt. each. These are placed four together, attached to strong hardwood frames by cast-iron guides, and caused to rise and fall sixty to seventy strokes per minute in a cast-iron stamp-box, weighing 13 cwt., which is fitted with false bottoms, cast in four pieces for facility of turning and changing about as they become worn. The cast-iron boxes are secured to a solid foundation. The stamps are raised by a cast-iron tapped barrel, fitted with wrought-iron cams, which act on tongues keyed upon the stamp-shanks. The two inner stamps are made to rise first and receive the quartz through a small aperture in the passes, together with a sufficient quantity of water. By the rapid, sharp falling of the stamps, the quartz becomes pulverized, and is washed by the water through fine iron grates, having forty-five to seventy perforations to the square inch (according to the fineness of the gold), fixed in position in the stamping-box, or by flushets, over which the reduced mineral is forced. Of the numerous appliances that have been patented for separating the gold from the pulverized quartz, the inclined plane with ripples, the shaping table, and the Chilean mill, each containing mercury, are principally used, the object in each being to bring the gold in contact with the mercury, and to form an amalgam. These processes continue according to the quantity and richness of the quartz to be reduced, and the gold is then cleaned up by working the table or mill with a regulated flow of water, washing off the quartz and lighter particles of other materials; and the residue, with the amalgam and quicksilver, is then washed by hand in an enamel dish, until the quicksilver is free from foreign particles. After being so washed, it is pressed by hand through chamois-leather, which retains the amalgam to be retorted. The quantity of gold in the amalgam depends on the quality of the former: if rough, coarse gold, the amalgam will only lose one-third; if medium-sized gold, one-half the amalgam will be lost; and when the gold is very fine, nearly two-thirds in weight of amalgam will be lost in retorting. The process of retorting is simple. The amalgam is placed in the cast-iron retort, which is carefully jointed and screwed; the retort is then placed on a large fire, and the end of a tube attached to it is placed in a bucket of water. As the retort becomes heated, the mercury is volatilized, and passes into the water, and the gold remains in the retort in one solid lump, nearly pure; it is then melted in a crucible, purified from any remaining dross with a little carbonate of soda, or borax, and cast in a mould ready for market."

CHAPTER III.

MACHINES FOR WORKING IN CLAY.

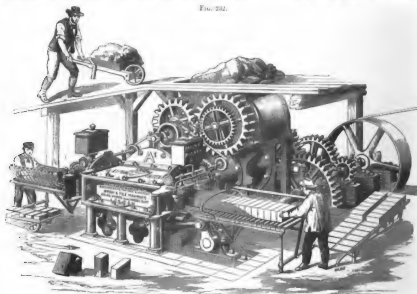
Brick and tile machinery, but a few years ago, was comparatively unknown to brickmakers or builders, bricks and tiles having been made by hand moulding. The irregular shape, variable consistency, and friability of hand-made bricks, together with a constantly increasing demand for them, drew the attention of engineers and machinists to the necessity of employing machinery in the manufacture of bricks. Brick-making machinery is of two general classes,—for working in wet clay, and for working in dry clay. The wet-clay machines have been more extensively employed than the dry-clay machines, as the machinery is simpler and cheaper, and the process of manufacture is more easily conducted by means of unskilled labour. The perfecting of the wet-clay machines has never-

theless been a labour of great difficulty and costly experiment, in which Messrs. Henry Clayton & Co. have taken a leading part, and to them no doubt belongs the merit of advancing the manufacture of wet-clay bricks by mechanical appliances into a regular factory system, independent of seasons or weather.

The wet and the dry processes are distinct in principle and in detail. In the wet process, bricks are formed by expression,—forcing clay through an orifice or die, which consolidates and shapes it during its passage; in the dry process bricks are formed by compression,—the clay being forced into moulds, arranged either in the periphery of a wheel or cylinder, or in a circular table, or in groups of single blocks.

Wet or Plastic Clay Machines.—The principal novelties in these machines consist,—first, in combining in one machine, and for one continuous process, the three distinct and successive operations of crushing, pugging, and brick-

FIG. 232.



WET-CLAY BRICK-MAKING MACHINE, by Messrs. Henry Clayton & Co., London.

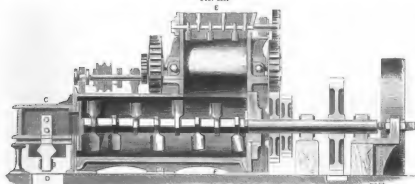
moulding; secondly, in the rotary cylindrical dies, both of which are due to Messrs. H. Clayton & Co., London. Great difficulty has been experienced in moulding by machinery the plastic clay into bricks, so as to obtain sound, sharp corners instead of the cracked or rounded ones too often met with in the productions of other machines. It is wholly overcome by Messrs. Clayton & Co.'s rotary dies. The great friction of the clay at the angles of common dies, and the oblique direction followed by a great part of

the expressed clay in escaping from the feed-box through the narrow matrix, tend to distort the semi-fluid prism of clay. But by substituting for fixed sides the revolving die at each end of the mould or ajutage from which the clay is expressed—retaining the fixed top and bottom,—the clay is relieved from the lateral friction of the fixed sides, and is gradually compressed and freely delivered with full unbroken corners. The rollers are covered with a cloth, stretched tightly round them, and kept

constantly moistened by a small stream of water from a small tank above each roller. The continuous rectangular prism of clay is cut up into bricks in the usual way, by a series

of wires in a rocking frame. The piston for expressing the clay is moved by a revolving crank with a connecting rod. Messrs. Clayton & Co.'s machines produce from 20,000 to 40,000

FIG. 232.

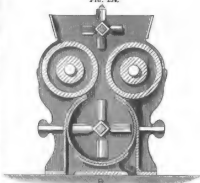


MESSRS. H. CLAYTON & CO.'S BRICKMAKING MACHINE. (Longitudinal Section of the Crushing and Pegging Machinery.)

bricks per day, according to the size of the machine. They are adapted for making solid, perforated, and tubular bricks, also tiles and pipes, by changing the dies at the orifices of the feed-box (figs. 232, 233, 234, 235).

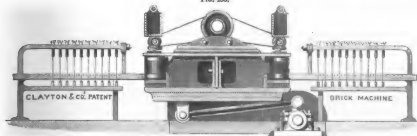
Mr. P. Effertz, Manchester, exhibited models of brickmaking machinery. "The clay is fed into a hopper, which opens into the machine; this hopper has in its interior, near an opening at the bottom, a shaft with revolving combs or beaters, by means of which the clay, partly prepared in this manner, is pressed into an elliptical vessel, called an elevator, close to the opening supplying the spiral knives, which are enclosed in the elevator, in which there is a grate or grid above the knives for the retention of stones or other objectionable matter. The knives raise the clay, which has been conveyed from the hopper through the grate, into a drawer which runs in grooves in the elevator. When

FIG. 234.



MESSRS. H. CLAYTON & CO.'S BRICKMAKING MACHINE. (Transverse Section of the Crushing and Pegging Machinery.)

FIG. 235.



MESSRS. H. CLAYTON & CO.'S BRICKMAKING MACHINE. (Sectional View of the Brick-moulding and Cutting Machinery.)

the drawer has been pushed forward, the clay is pushed out over the mould, which is then closed,

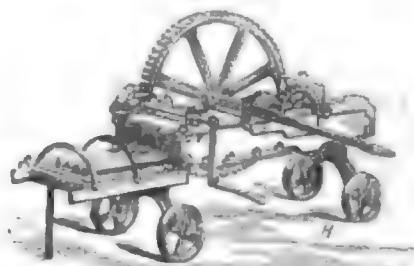
and on the same level as the elevator, and is then pressed into the mould by means of a closely-

fitting presser. According to the size of the machine, from four to ten bricks may be formed in the moulds. After the pressure, the piston is moved out of the drawer, when the latter moves back again over the elevator to be filled afresh. During the time of refilling, the piston descends once more, and when coming up again the bricks are raised in conjunction with a pusher, which, during the pressure, forms the bottom of the moulds. The bricks are then pushed by the returning drawer on to an endless apron. After pushing them off, the pusher moves back again into the moulds, and the movement of the machine is repeated. According to the number of bricks to be produced, an elevator receives on one or both sides the above-mentioned presser, which works in such a manner that one piston ascends as the other descends, in order to raise the bricks previously pressed by it. The drawer must have two parallel compartments, so that when one is empty, the other one may stand over the elevator for re-filling. The brick machine can be made to be driven by steam-engines fixed on the top of the machine (the boiler being then alongside the brick machine), or by spur-wheels or belts from fixed or portable steam-engines."

Messrs. E. Page & Co., Bedford, exhibited three machines for making bricks, pipes, and

makes draining pipes up to 7 inches in diameter (fig. 236). 2. *A Single-chamber Brick, Pipe, and Tile Machine*, for hand-power; in which the piston is driven by means of a double rack and two pinions. It is capable of making pipes of from $1\frac{1}{2}$ to 13 inches in diameter (fig. 237). 3. *A Small Single-chamber Pipe and Tile Machine*, for hand-power, similar to the preceding machine, but fitted with one rack only; adapted for small tileries, or on private estates. It can be worked by a stout lad (fig. 238).

FIG. 236.



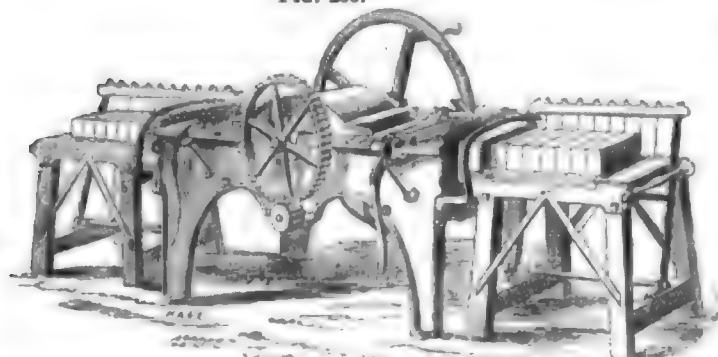
SMALL PIPE AND TILE MACHINE, by Messrs. E. Page & Co.

Messrs. Sharp & Bulmer, Middlesboro, exhibited a *small hand-power brick and tile-making machine*, to turn out 5,000 bricks, or 10,000 2-inch draining tiles per day. The motion is continuous, the machine being fed with clay while at work. Elliptical gearing is employed for the purpose of varying the speed, and consequently the pressure, during each revolution, in the proportion of six to one, so that speed is gained where wanted in the process, and leverage for thrusting out the bricks. The bricks are walled direct from the machine (fig. 239).

M. Cazenove, Paris, exhibited a novel mode of cutting off the bricks of the required dimensions from the stream of clay, with sharp, rectangular corners. The clay is delivered on an endless revolving series of planks, each plank carrying a catch, which, as it moves forward, engages the cutting wire, which is stretched upon a double wheel frame, and pushing it before it, causes it to descend upon the clay by the rotation of the wheel frame, and to make an exactly vertical cut through the clay, to form two sides of the bricks. This machine, worked by hand, cuts off 10,000 bricks per day.

Dry-Clay Machines.—These machines operate on the principle of forcing dry or semi-dry clay into moulds by strong pressure. Plastic clay can be moulded into bricks by much less pressure than when in a dry state, and the bricks made by it are more coherent; but, by using semi-dry clay, many inconveniences attached to the plastic system are entirely obviated. For example, by using semi-dry material, the bricks are not handled while in a condition liable to be deformed and distorted; and the drying of them is done away with, by which a great deal of time is saved, as well as the risk

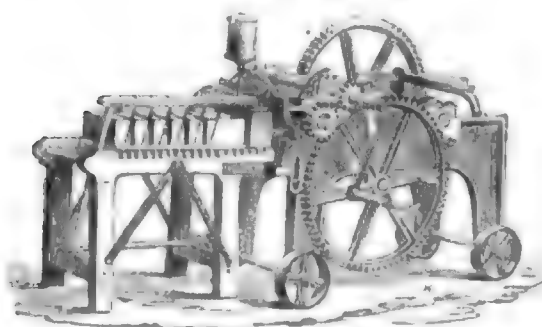
FIG. 236.



DOUBLE-CHAMBERED BRICK, PIPE, AND TILE MACHINE, by Messrs. E. Page & Co., Bedford.

tiles :—1. *A Double-chamber Brick, Pipe, and Tile Machine*, for hand, horse, or steam power; in which the pistons are driven by an eccentric,

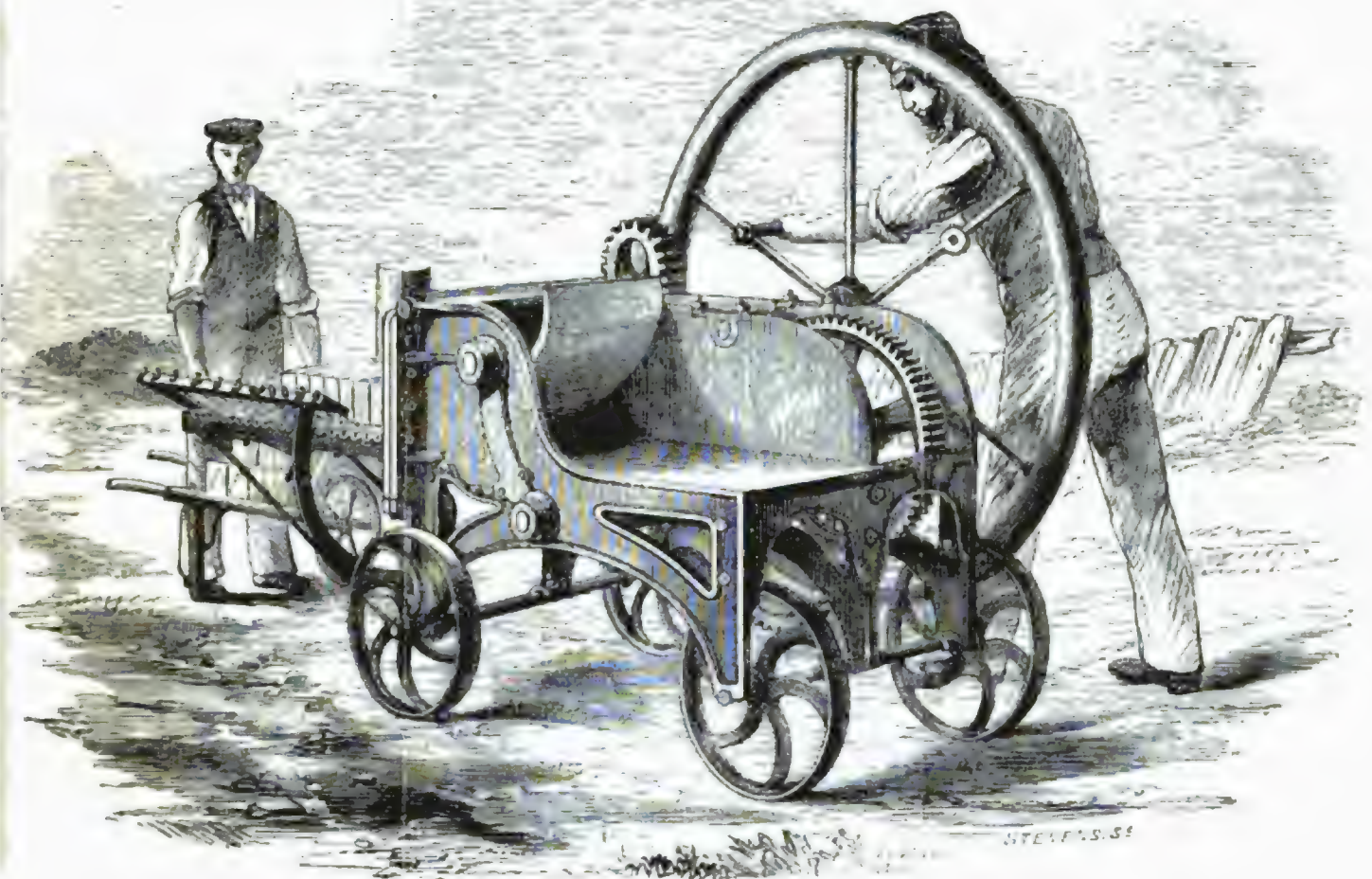
FIG. 237.



SINGLE-CHAMBERED BRICK MACHINE, by Messrs. E. Page & Co.

instead of a rack-and-pinion, causing one box or cylinder containing the clay to be emptied whilst the other is being filled. The machine

FIG. 230.



BRICK AND TILE-MAKING MACHINE, by Messrs. Sharp & Bulmer, Middlesboro.

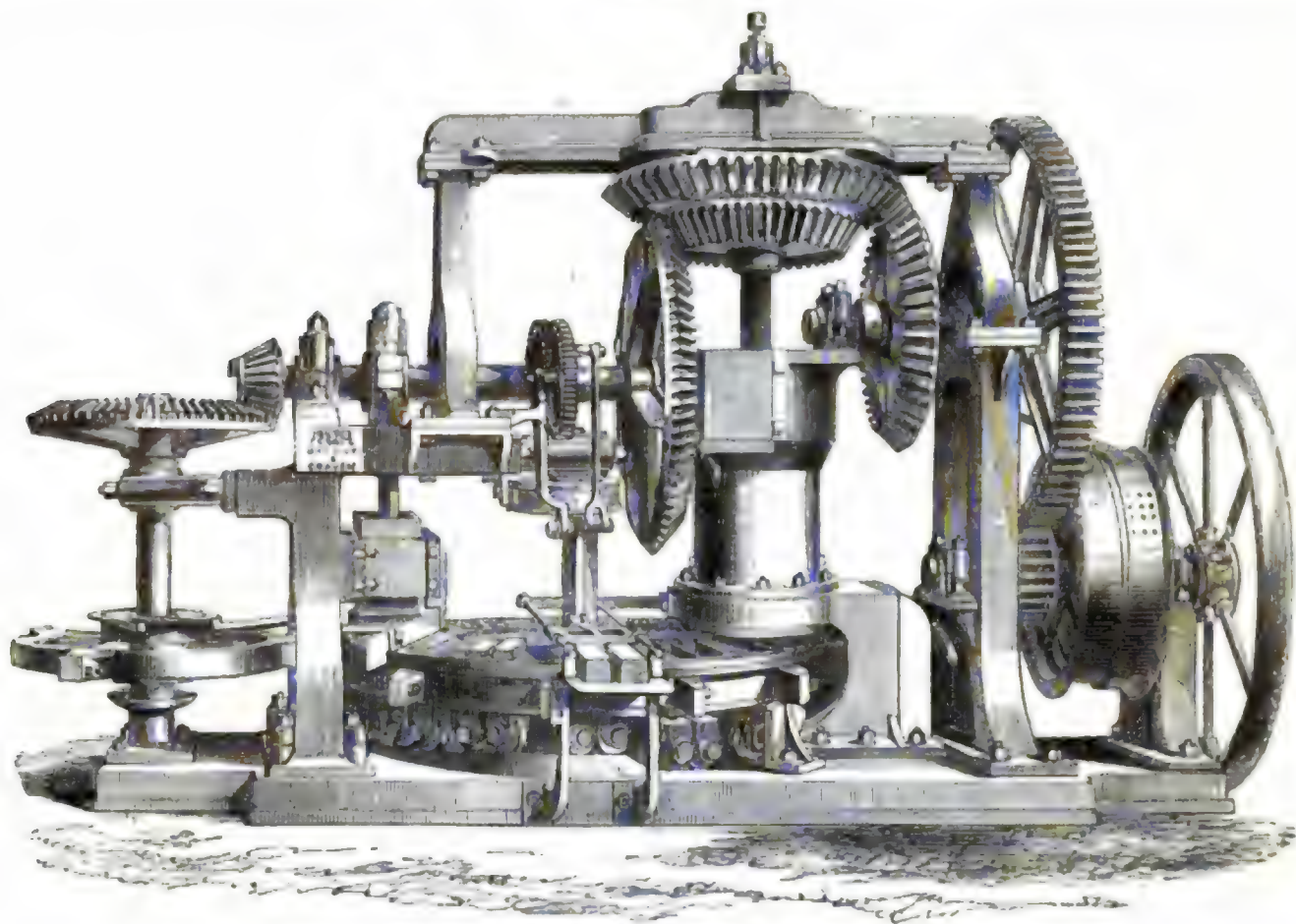
of damage by wet weather. The clay might be used in the state of semi-dryness in which it commonly leaves the earth. Bricks made by this process are remarkable for external accuracy and beauty; they can be moulded in a great variety of shapes and ornamental designs without additional cost.

Mr. W. Wilson, Glasgow, exhibited a *semi-dry-clay brickmaking machine* specially adapted for making fire-bricks, in which the dry pulverized clay is prepared for the pressure it is intended to receive by conveying it through a chamber filled with steam, where it is partially softened, and rendered plastic by the condensation of the steam; consequently only a moderate pressure is required, which is regulated by a hydraulic buffer acting between the brick and the compressing ram. In this way the machinery is neither stopped nor broken by stones accidentally in the way, or by any excess of clay in the mould. A hopper is placed above the moulding-table, which contains the horizontal moulds, within which an upright shaft carrying four blades is kept in continual motion, so as to fill the mould thoroughly during its short stoppage. Two compressing cylinders are placed opposite each other under the circular moulding-table; the first one compresses the soft clay to a certain extent, and the second gives the final

compression. The brick is then forced out of the mould by means of its respective compressing plunger, which, in the order of the circular motion of the table, glides up a fixed incline and is forced into the mould. The bricks made by this machine are said to be capable of being stacked in the kiln and burnt forthwith, without any process of drying; and the machine is said to be capable of turning out 20,000 bricks per day.

Messrs. Bradley & Craven, Wakefield, exhibited a *dry-clay machine*, in which the clay is delivered as it leaves the earth, without any addition of moisture, and, after its pulverization, is introduced into one pair of moulds placed on a rotating table, while two others are submitted to strong pressure by pistons; and the bricks are discharged from the moulds by a fixed incline, upon which the lower end of the piston is obliged to travel. This machine produces 15,000 bricks per day. The same firm construct larger machines, in which the pressure is given first by a piston, forming a movable bottom to the mould, and afterwards by another piston working downwards. By this contrivance the diminution of pressure in the bottom layers of clay, when compressed only from above, is obviated, and all the corners come out equally sharp and finished (fig. 240, page 256).

FIG. 240.



DRY-CLAY BRICK-MAKING MACHINE, by Messrs. Bradley & Craven, Wakefield.

Messrs. Platt Brothers & Co., Oldham, exhibited samples of bricks manufactured by them by the dry-clay process. The machinery for this purpose, invented by them, has been very fully matured in all its departments. It was too large for exhibition; but the annexed description, with the illustrative plates, elucidate the arrangements very completely (Plates XIX. to XXV.)

The clay is, in the first place, excavated and filled into iron waggons, which are moved on iron rails to the foot of an incline, upon which they are drawn up by a power-crane, and tipped into a hopper, in which the larger pieces are divided by means of two screws revolving at different speeds in contrary directions. The screws approach each other at their upper surfaces, and are carried in two channels forming the bottom of the hopper. The larger pieces are broken by the forcing action of the screws over the ridge which separates the channels; and the clay is forced by the threads of the screws through the channels into a drying cylinder to which the hopper is attached. The third operation is to dry and further to reduce the pieces of clay, by passing them through the drying cylinder. This cylinder is 5 feet in diameter and 35 feet in length, and is placed in an inclined position, and carried upon and rotated by friction-rollers on a longitudinal shaft. The cylinder is fitted in the interior with six lines

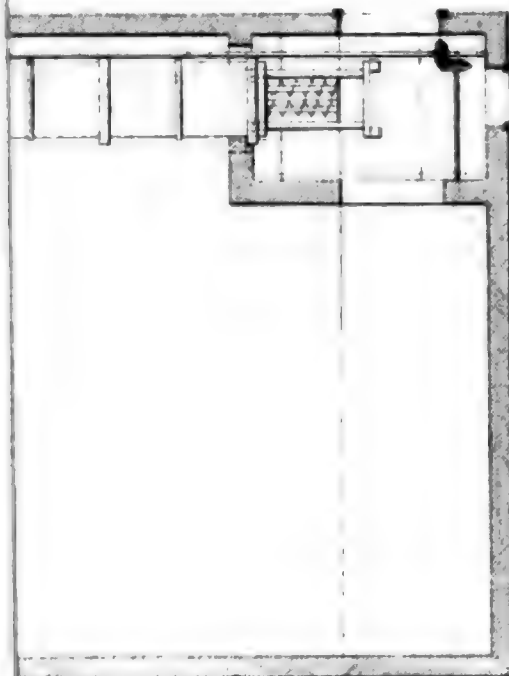
of shelves on the circumference, running longitudinally, and fixed at a suitable angle to lift the clay from the bottom to nearly the top, when the clay falls off the shelves. The cylinder is made with two series or rings of spaces, ten feet apart, through which the smaller pieces of clay fall into a trough beneath the cylinder, whilst the larger pieces advance to the end, where they fall upon one side of an inclined grate-hopper, and are sufficiently divided by a series of rings or revolving pick-points protruding through the spaces between the bars in the bottom of the hopper, when they drop through. The clay is dried by a fan-blast of hot air forced through the cylinder, by which the vapours are carried off to a funnel at the top and over the hopper. The hot air is drawn from the kiln in which the bricks remain for cooling after having been burnt, or by a fire and flues in the floor under the cylinder. By the constant fall of the clay through the hot air, it is dried and broken down as it advances through the cylinder. The trough beneath the cylinder extends under the hopper, to receive the final discharge from it, and is furnished with a propelling screw, to convey the clay to the pulverizer. The trough is covered, except where it is open for receiving the clay, and a fan-blast of hot air is forced through it, from which the screw absorbs and transmits the heat further to dry the clay in which it revolves. In

CLAY BRICKMAKING MACHINERY

BY

MESS^{RS} PLATT BROTHERS & CO OLDHAM

GENERAL PLAN OF THE BUILDINGS & MACHINERY

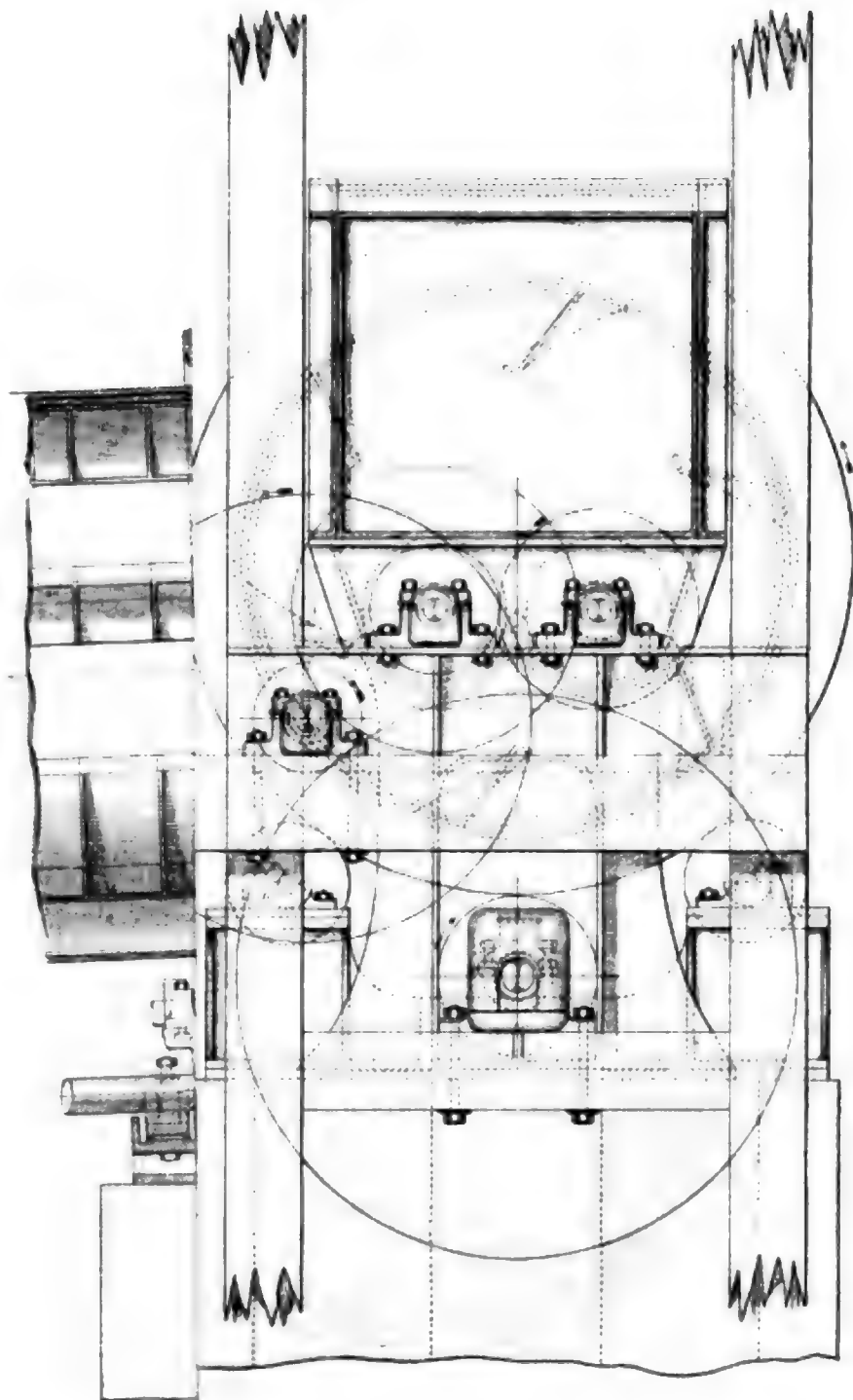


Drawn by J. H. Platt, Esq. the architect.

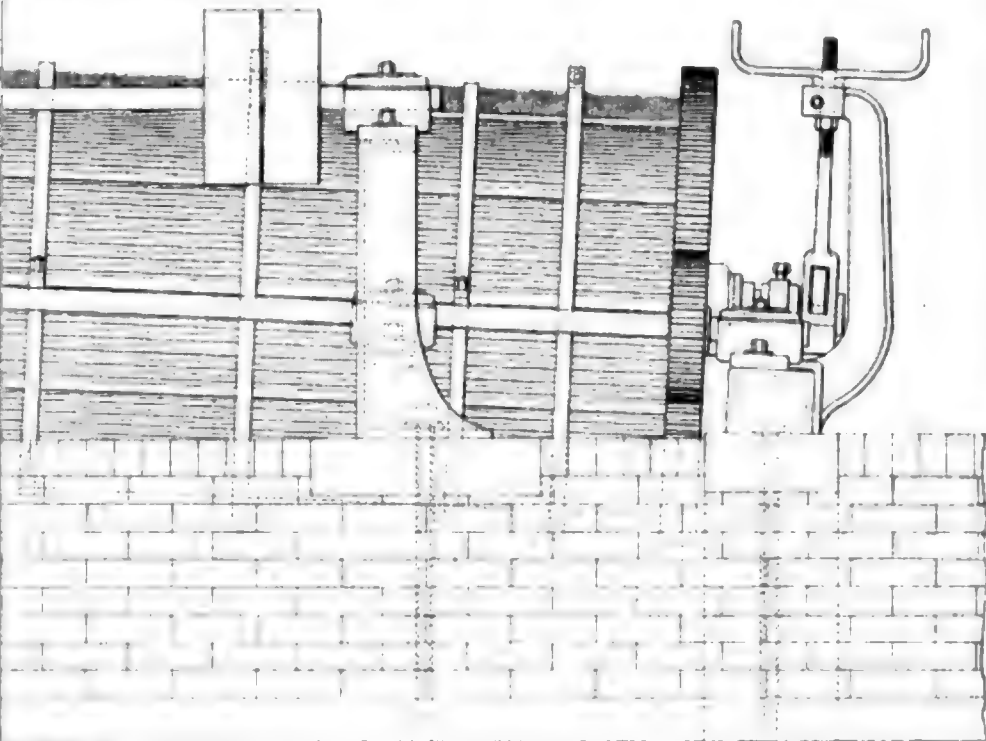
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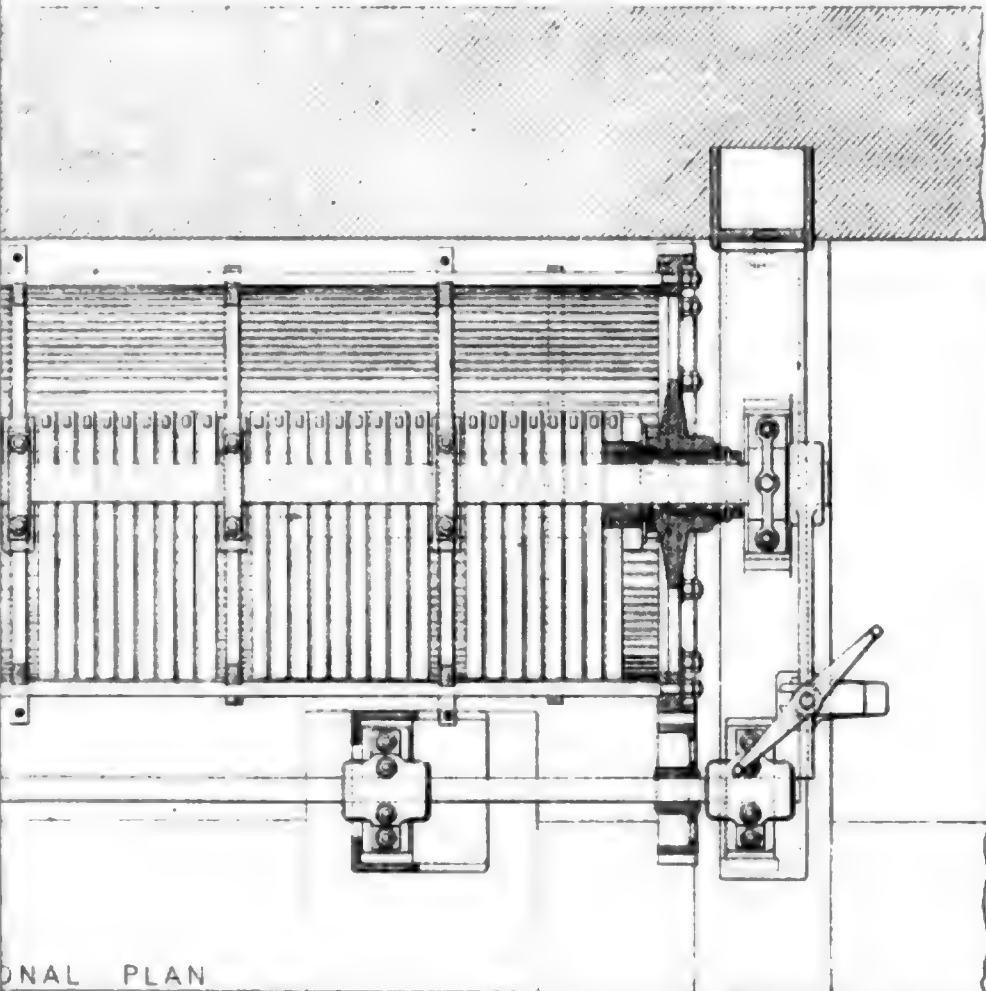
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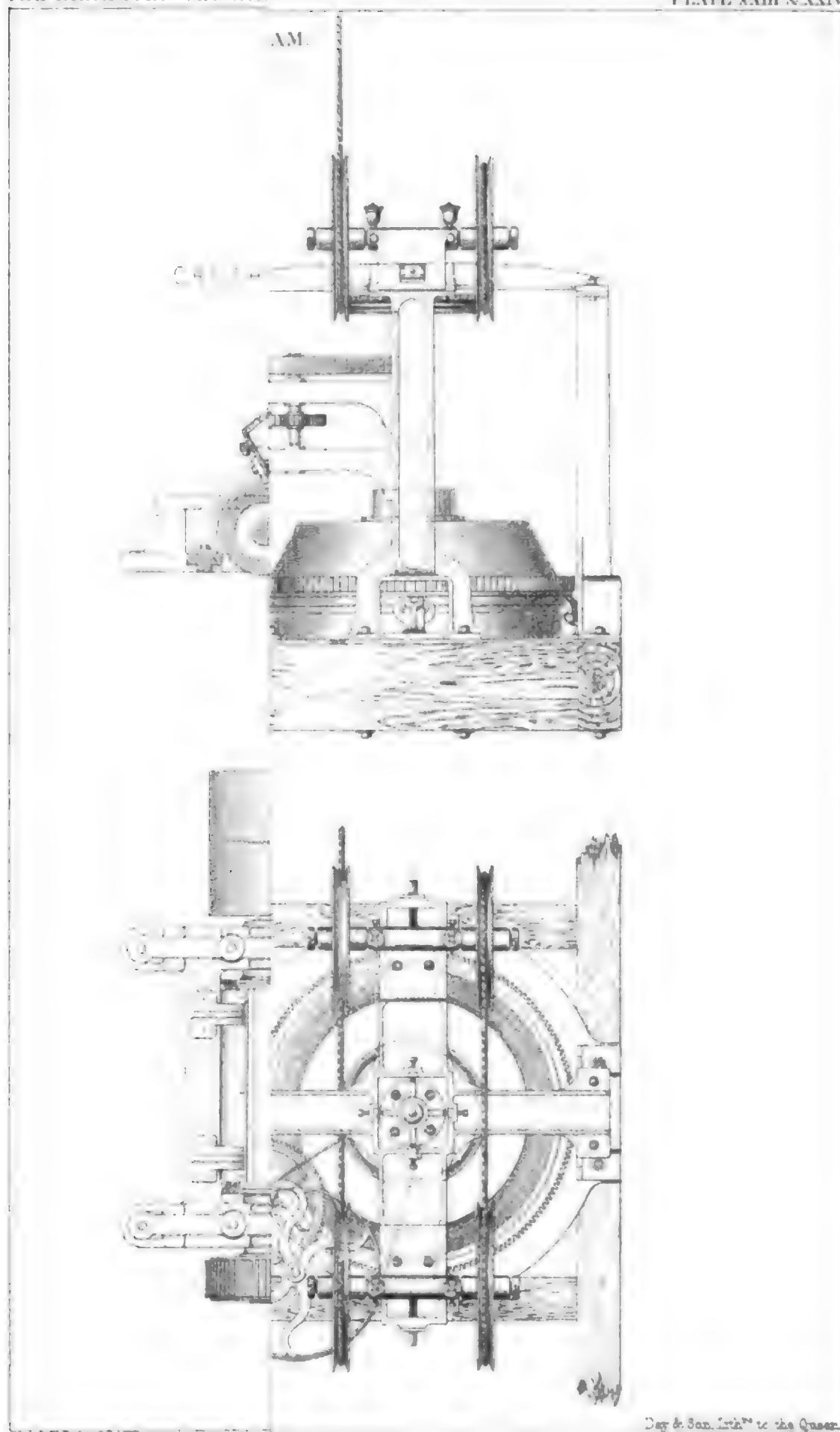


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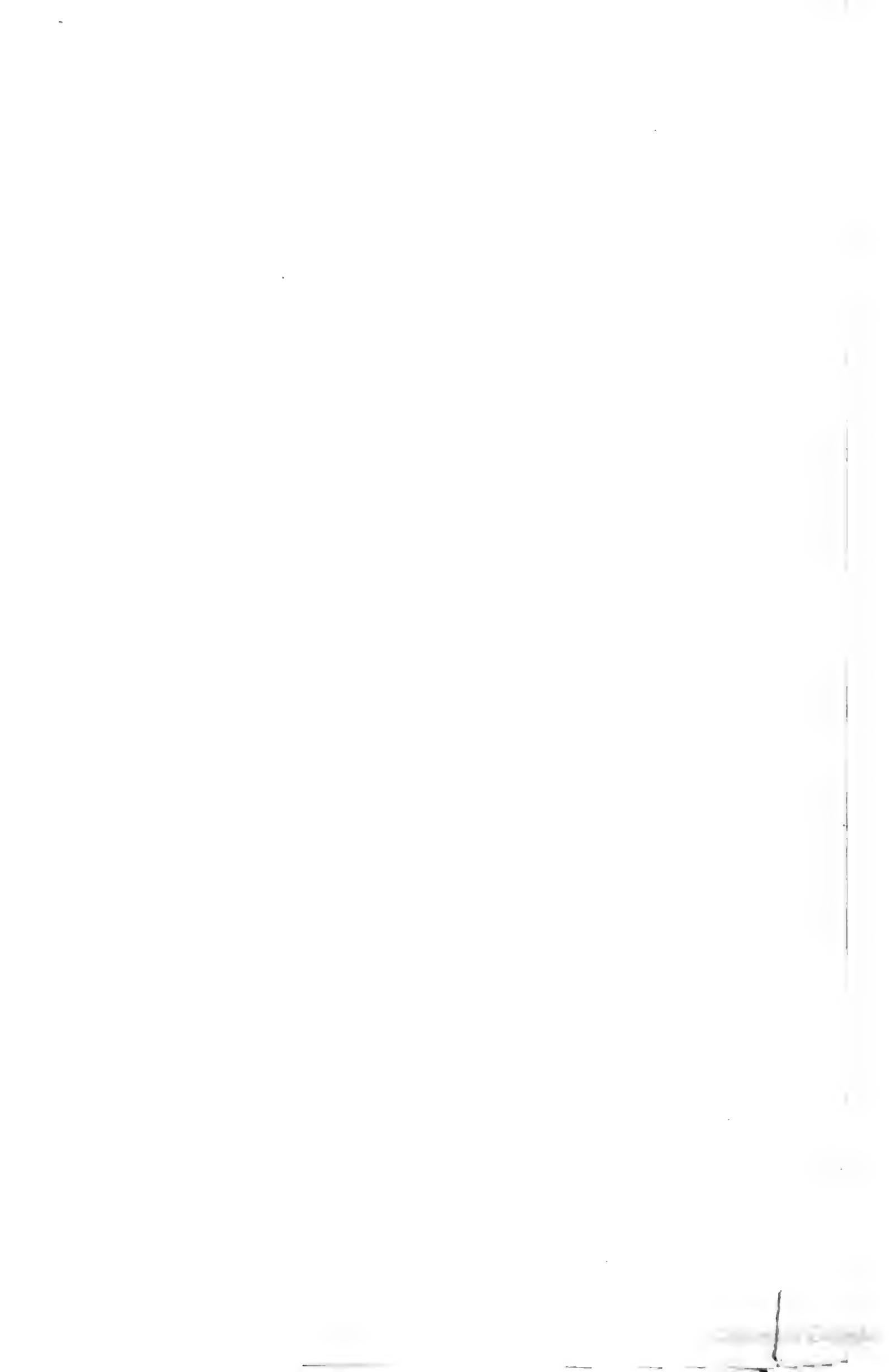
Day & Son Lath^{rs} to the Queen



SEP PLA'



FOOT



the pulverizer it is reduced to powder, with pieces not exceeding the size of a pea, the larger pieces or stones being separated. The pulverizer is cylindrical, 3 feet in diameter and 8 feet long, formed of bars of iron placed longitudinally, of a truncated wedge-form in section, $\frac{1}{8}$ inch apart at the inner sides, and $\frac{7}{8}$ inch at the outer side, leaving taper interspaces to allow the clay to pass freely through between the bars. The cylinder makes twenty-five revolutions per minute, on an inclined axle, which is stationary. A number of weights or pulverizers are attached to two bars of irons within the cylinder, one as a fulcrum, and the other as a rest. They are serrated on the under side, which is formed to a slightly flatter curve than the inside of the cylinder, thus approaching nearer to the surface of the cylinder at their ends than at the middle or lowest part, in order to allow the clay and stones to enter the interspace, by the motion of the cylinder, to be crushed as they are carried round towards the ends of the pulverizers. The upper sides of the pulverizers are inclined, to induce the clay and stones that have passed unbroken to roll back to the bottom of the cylinder, and pass under another of the weights to be crushed. The lower end of the pulverizer is open for the escape of the unbroken clay and stones. The clay which falls through the pulverizers is collected in a hopper, from which it is taken by an elevator-strap with small buckets, and delivered into a spout, from which it falls, and is conveyed to two pairs of chilled rolls, which crush the stone to dust and spread the clay into small sheets. From a hopper below, the materials are again elevated and delivered into a spout, from which they fall to the centre of a disintegrator, by which the sheets of clay are reduced to a fine moist powder. The disintegrator consists of a disc 30 inches in diameter, on the lower end of a vertical spindle, with four concentric rings of round iron pins 8 inches long, fixed into the disc, parallel to the axis, and united at the upper ends in a round plate of iron, with an

aperture at the centre to admit the clay. The innermost circle of pins is 12 inches in diameter. This apparatus revolves within a casing, and makes 700 revolutions per minute, and by its centrifugal action breaks up the whole of the clay into powder, in the course of its passage through the successive cages. The clay is collected at the bottom of the casing, which is formed conically, to discharge the clay, and revolves at a slow speed. By means of a fixed scraper at the lower part, the clay is prevented from accumulating in and adhering to the hopper. The clay thus discharged is delivered into a hopper to feed the press, in which it is made into bricks.

The bottom of the hopper, or the charger, as it is called, is moved by means of cams and levers, with a reciprocating sliding motion; in the front portion of the charger there are four cavities which are filled with clay-dust from the hopper when they are under it. The charger is then moved over the moulds, when it passes under an adjustable striker, by which the proper quantity of dust to form a brick is measured, when the upper piston falls and finishes the charge. The charger being then withdrawn, the piston falls a second time, and the brick receives a double pressure from two pistons, one from above and one from below, respectively depressed and elevated by cams, but at different rates, so that the newly-formed brick is slightly shifted vertically in the mould while receiving the final pressure.

By the application of this slight vertical movement, the brick is prevented from sticking to the mould, and is readily lifted from it entire; the brick is lifted by the action of the lower cam, which raises both the lower and upper pistons. There is a series of upper and lower pistons and moulds, which are acted upon by a single cam above, and another below. The charger, in supplying the next feed, pushes off the newly-formed bricks, to be removed by hand, and burned. This machine is capable of turning out 20,000 bricks per day.

SECTION VI.

MACHINES FOR WORKING IN SUGAR AND OIL.

CHAPTER I.

SUGAR-MILLS.

In the display of sugar-mills at the Exhibition, most observers probably remarked the massive proportions of the English machinery. To foreigners, and even to Englishmen at home, they

appeared excessively strong, and overdone in their massiveness; and they have been freely criticised from this point of view. But there is no difficulty in finding faults where experience is wanting to guide the judgment; and amongst other comparisons, the comparison of a sugar-mill steam-engine with a locomotive engine is eminently irrelevant; for though in a locomotive the machinery may be ob-

jectionably heavy, and it is sought specially to combine compactness and lightness with strength, the exigencies of a sugar-mill steam-engine are distinctly different. The first point of all is to obtain enormous strength and stiffness, and this can best be done by the unsparing use of material. Breakages frequently occur of the very strongest sugar machinery, through sheer carelessness or deliberate negligence. Negroes in the sugar-growing countries, when they want a holiday, drop a piece of iron, or, if that will not do, a cold chisel, amongst the gearing, and break it, or overstrain the machinery.

But sugar-grinding machinery undergoes its severest trials from careless feeding of the canes to the mill, by the irregular distribution of the canes upon the cane-carrier. Should a few feet of the cane-carrier be but thinly supplied with cane, and followed by a large dense bundle, the engine has time to run off at a high speed, when it may in full swing be brought up to a dead stand in a few strokes, by a mass of canes utterly out of proportion to the spaces at which the rollers are set. Hence the extreme necessity for extra strength in the gearing and framework.

There are no doubt also the prejudices of the users of sugar machinery to contend with. Some, as the Spaniards, like ornament and bright work; the English abroad will not have it, and would probably put a coat of tar upon a polished column. But everybody likes the appearance of a well-made six-column beam-engine; and if users choose to have and to pay for it, there is no good reason why it should be abandoned for the horizontal engine.

According to the regular practice of sugar-mill constructors, the machinery is divided into and treated as three distinct portions,—the steam-engine, the gearing, and the mill,—which are placed on independent base-plates and foundations. It is the practice in Cuba to range the base-plates on one level; but in the British plantations they are generally ranged on different levels.

Sugar-cane contains from 80 to 90 per cent. of its own weight of juice, holding in solution about 20 per cent. of pure sugar. Of this quantity, about one-half is, by the usual process of manufacture, obtainable in the form of crystalline sugar, whilst the remainder is converted into molasses and rum. In order to express from the cane the greatest possible amount of juice, many ingenious modes of pressing have been suggested and tried, but they have all been found to be inferior in efficiency to the method of crushing by rollers; and of this form of machine, it has been proved by experience that a well-proportioned three-roller mill combines in the highest degree the requirements of simplicity, efficiency, and durability.

Sugar-mills of the largest dimensions, like that exhibited by Messrs. Mirrlees & Tait, are

mostly required for the island of Cuba, where, from the immense extent of land under cultivation, and the comparatively short period (from four to five months) in which the crop is to be manufactured into sugar, not only has a large amount of work to be performed in the given time, but there must be the utmost amount of security against breakage of any important parts. Instead of one mill of such large proportions as Messrs. Mirrlees & Tait's, having 33-inch rollers, 7 feet in length, it is occasionally the practice to connect two mills of smaller size to the same engine. Next to Cuba, in the employment of such large crushing power, ranks Demerara; then Mauritius, Surinam, and Porto Rico; whilst mills with rollers 26 and 28 inches diameter and 5 feet long may be found all over the West Indies, at Port Natal, and even at the Sandwich Islands.

Messrs. Mirrlees & Tait, Glasgow, exhibited one of the largest and most powerful *sugar-mills* now in use. This mill has been maturely and substantially designed, and solidly constructed; it is capable of expressing with ease 4,000 gallons of juice per hour, yielding about two tons of sugar. The production for one season of 100 days amounts to from 4,000 to 5,000 tons of sugar. (Plate XXVI.)

This sugar-mill consists of a six-columned high-pressure beam-engine, having a cylinder 22 inches diameter, with a stroke of 4 feet 6 inches, making thirty-four revolutions per minute. The usual working pressure employed is 70 lb. per square inch. The steam is admitted to the cylinder by the usual three-port slide-valve cutting off at three-fourths of the stroke, while a further degree of expansion is provided for by a separate grid-iron expansion-valve, having a slotted-link motion, adjustable to any degree of expansion whilst the machinery is in motion. For the manufacture of sugar, however, there is not much importance attached to nicety of expansive working, as the engines are invariably worked to the utmost extent of their capability, whilst the heat of the exhaust steam is economically made use of in the clarification and evaporation of the cane-juice. For this reason, as well as for greater simplicity, non-condensing engines are preferred to condensing engines.

The power of the engine is transmitted, and the speed reduced to the required velocity of rollers, by a heavy train of compound gearing, firmly secured to a massive cast-iron bed-plate on the same level as that of the engine. The reduction of speed is effected by the gearing in two stages, and is as 16 to 1, the rollers making one revolution for sixteen revolutions of the engine.

The mill proper is a three-roller mill, with rollers 33 inches diameter and 7 feet long. The bed-plate, which also forms a trough for the reception of the cane-juice as it falls from the rollers, is of cast-iron, and it weighs over 5 tons.



The headstocks or mill-checks, which carry the bearings of the three rollers, are fixed to the bed-plate. These are necessarily very heavy, having to receive the whole strain of the work performed, which may be at this point taken as the whole force of the engine acting through a leverage of 16 to 1. The centres of the top roller are a fixture, being placed directly in a line with the shaft of the large gearing-wheel. The roller is secured from rising by heavy covers of cast-iron, fixed down by four wrought-iron bolts $4\frac{1}{2}$ inches in diameter, which, extending downwards completely through the metal of the headstocks and mill-bed, are secured by cottars and wrought-iron plates underneath the heavy timbers on which the mill rests. By thus carrying these bolts down through the mill, not only is the headstock relieved from strain, but the additional elasticity of long bolts and timber beams is obtained, permitting the top roller to yield to a certain extent to the extraordinary pressure occasioned by the frequent gluts of canes supplied to the mill. The side rollers are of the same dimensions as the top roller, with strong flanges in addition at the ends, between which the top roller revolves, thus preventing the canes escaping past the ends of the rollers. The two side rollers are each separately adjustable, in a horizontal direction, to any required distance from the top roller, by means of powerful set-screws fitted into the outer ends of each headstock. Each of the side rollers is adjusted separately in relation to the top roller. The front roller, or that which first receives the canes, is usually kept to a distance of from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inch apart from the top roller, so as readily to bite and take through the mass of canes supplied to it from the cane-table. The cane-table is a malleable-iron plate of the same width as the rollers, and rising from the front roller at a considerable angle to about 5 feet in height. This table is attached to cast-iron sides, which confine the canes sidewise when falling into the mill, and are attached to the headstocks at each side, and also to a cast-iron frame-work, which carries the driving mechanism of the cane-carrier.

The cane-carrier consists of two endless chains revolving on two drums, one of which is placed at the top of the cane-table, and the other at any distance, according to the length of cane-carrier required. The length for a mill of this size is generally from 100 to 120 feet. The chains may either be at the ends of the drums, or nearer, but they are connected together by strips of board fastened to each link, about 5 or 6 inches broad, and generally of the same length as the rollers, forming a complete endless travelling table. Motion is given to this table by a pair of pitch-chain wheels, one on the end of the front or cane-roller gudgeon, and the other on the upper drum-shaft, and of such proportions that the surface of the table shall move at a rate of from one-sixth to one-third slower than

the surface of the rollers. An ingenious double-cone friction-clutch is provided, whereby the carrier may be instantly stopped or started. Another apparatus of similar design is attached to the other side of the mill, for receiving the megass or crushed cane after being separated from the juice, and carrying it clear of the mill-house, for the purpose of being stacked, or of being made use of. This megass or refuse cane is the principal, and in many cases the only, fuel employed in the manufacture of sugar; and the state in which it is delivered from the mill is a matter of some importance. Should the back roller be too close for the amount of canes passing through, the megass will be reduced almost to a state of powder, which, when dry, is too light and volatile to be of much use as fuel; and, again, if the rollers are not close enough, the megass will contain too much juice, to the serious loss of the planter, and will, if not very speedily dried again, suffer deterioration as fuel by the acetic fermentation which immediately sets in. The quality of the megass is again affected by the velocity with which it is passed through the mill, and on this point almost every maker and every planter holds particular opinions. A circumferential speed of roller-surface of about 18 feet per minute is found to produce very good results, delivering the megass in good condition, and extracting, if the rollers be properly adjusted, between 65 and 75 per cent. of juice from the cane.

To estimate the amount of work that can be done by a mill of this description, the quantity of canes passing through the mill in a given time may be deduced from the speed of the cane-carrier. In a machine of this size, the cane-carrier is continually kept filled with canes to a depth of from 12 to 14 inches, which, at 7 feet wide and 15 feet per minute, gives a delivery of about 6,500 cubic feet per hour, which, packed in that manner, yields about 4,000 gallons of cane-juice, equivalent to, say, 2 tons of dry sugar per hour.

Although, as already stated, the mill can express this quantity of juice, under ordinary circumstances, with canes of average ripeness, yet, in order fully to provide for the occasional crushing of more watery canes, the pump which receives the juice as it flows from the mill-bed and delivers it to the steam clarifiers or other receivers, is made of sufficient capacity to raise at least one-fourth more.

The following particulars of the weight of the sugar-mill exhibited by Messrs. Mirplees & Tait show how the mass is distributed, in the three divisions of the mill, thus:—

	Tons	cwt.	qr.
Steam-engine	44	9	0
Gearing.....	37	0	0
Mill	62	0	0

TOTAL WEIGHT.....143 9 0

These are detailed in the subjoined list:—

Steam-engine—

	Tons	cwt.	qr.
1 Sole-plate	7	14	0
1 Entablature	3	5	2
1 Working Beam	2	5	0
6 Side Columns	5	2	0
1 Cylinder and Casing	2	10	0
1 Fly-wheel	13	10	0
1 Crank Shaft	2	2	0
Other articles not particularly heavy	8	0	2
	44	9	0

Gearing:—

	Tons	cwt.	qr.
1 Bed-plate in halves	7	2	0
1 Large Spur-wheel	11	10	0
1 Second size Spur-wheel	2	8	0
1 Spur-wheel Shaft	2	13	0
2 Couplings	2	7	2
2 Stools and Pillow-blocks	4	7	0
Other articles not particularly heavy	6	12	2
	37	0	0

Sugar-mill:—

	Tons	cwt.	qr.
1 Mill Bed-plate	5	2	0
2 Mill Headstocks	11	2	0
2 Covers for ditto	1	9	0
1 Top Roller and Gudgeon	9	15	0
2 Side ditto ditto	17	14	0
3 Roller Pinions	3	10	1
1 Liquor Pump and Tank	2	3	0
Other articles not particularly heavy	11	4	3
	62	0	0

TOTAL WEIGHT (say) 113½ TONS.

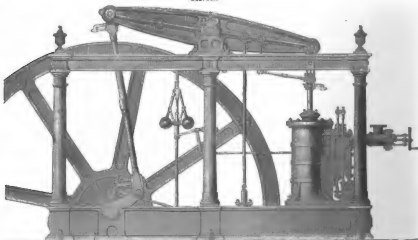
Messrs. W. & A. McOnie, Glasgow, exhibited a 30-horse power sugar-mill and beam-engine in

complete working order,—well designed and well constructed. The cylinder is 21 inches in diameter, with a 3½-feet stroke; and is fitted with a variable expansion-valve, working on the back of the ordinary valve, the travel of the valve being variable, by varying the throw of the eccentric. The fly-wheel is 18 feet in diameter, and is keyed upon a square shaft, in preference to a round one, the better to resist the violent strains of the mill. The governor is driven by means of a neatly constructed pitch-chain passed over steel teeth fixed on the circumference of the crank eye or nave, made to act as a driving-wheel. The fly-wheel shaft, crank, connecting-rod, beam-centres, and other working parts are of forged iron. The engine was regulated to make 36 revolutions per minute, and to work up to 70 or 80-horse power.

The rollers are 28 inches in diameter, by 5½ feet long. The mill bed-plate forms the receiver for the cane-juice; the cheeks are made with removable diagonal stay-bars and filling-blocks, for readily removing or replacing the side rollers. The upper roller is held down by two 4½-inch iron bolts, passed down through the mill and the foundation beams of timber. The elasticity of the timber cases the mill when unduly fed with cane. The front roller is set by set-screws, ¾ inch apart from the top roller, and the back roller is set nearly in contact with it. A "dumb turner" is placed between the side rollers for advancing the canes after having passed the front roller, for a second squeeze between the back and top rollers.

The engine is connected to the mill by double-

FIG. 241.



30-HORSE-POWER NON-CONDENSING STEAM-ENGINE, FOR SUGAR-MILL, by Messrs. W. & A. McOnie, Glasgow.

spur-gearing, of which the rim of the largest wheel is built in segments. The gearing is so

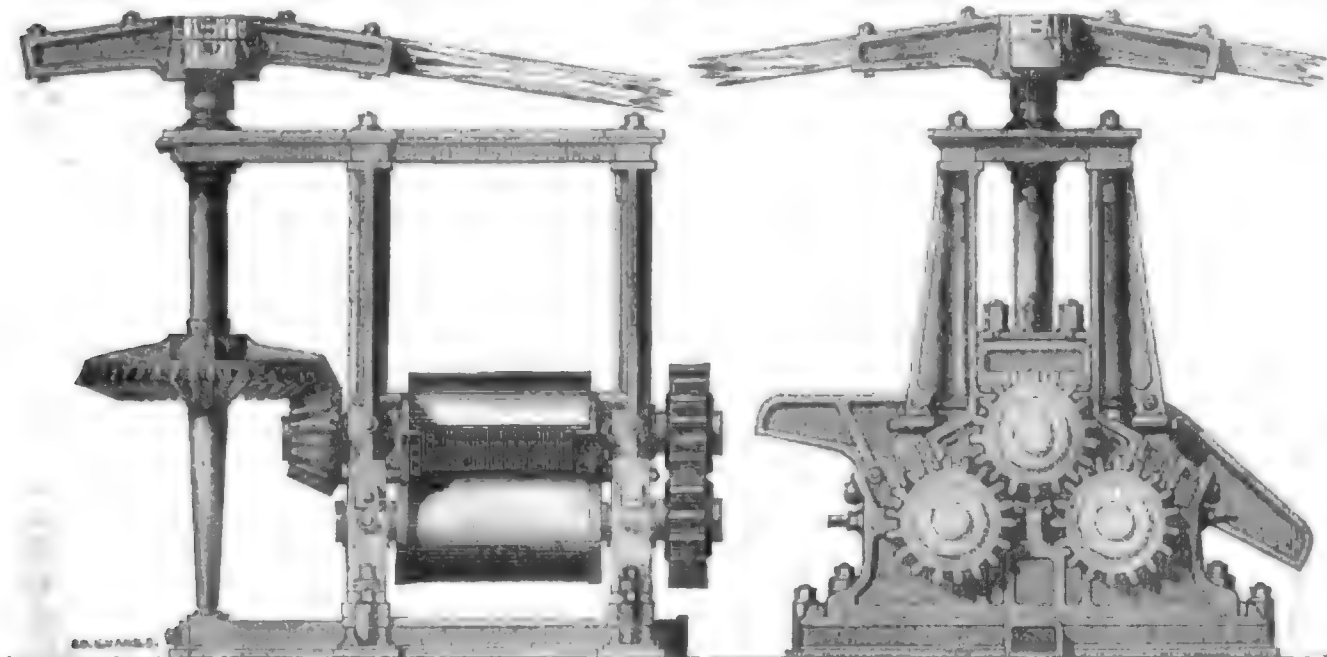
proportioned as to give to the rollers a circumferential velocity of 19 feet per minute (fig. 241).

Sugar-mills of this size are in use on sugar estates in Trinidad, Demerara, Mauritius, Cuba, Porto Rico, and Java; and they are capable of producing 12 tons of sugar per day, or about 1 ton per hour. The same constructors have made sugar-mills with rollers 3 feet in

diameter, and 70 to 80 horse-power engines, working to 200 horse-power, weighing in all 200 tons.

Messrs. M'Onie exhibited also a small *sugarcane mill*, nominally of 4-horse power, with rollers 16 inches in diameter and 2 feet long,

FIG. 242.

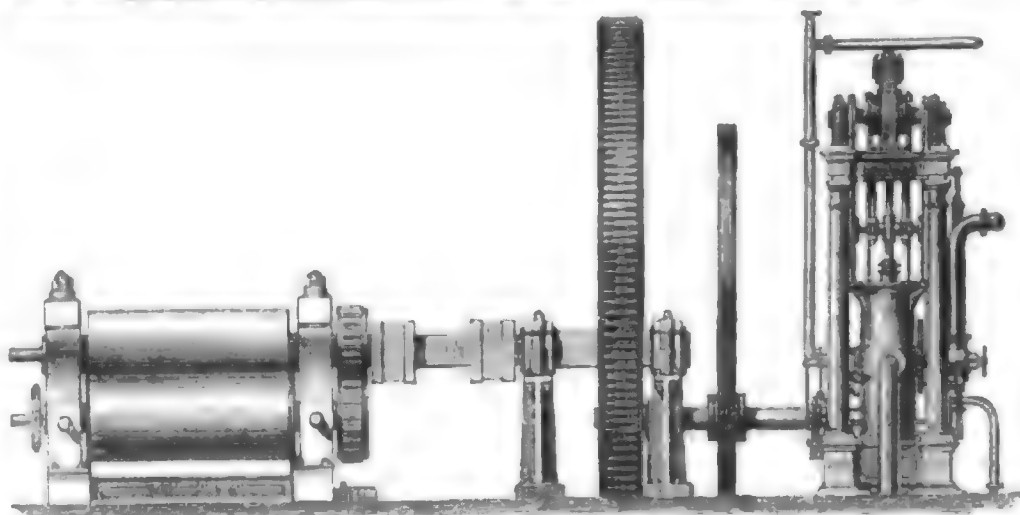
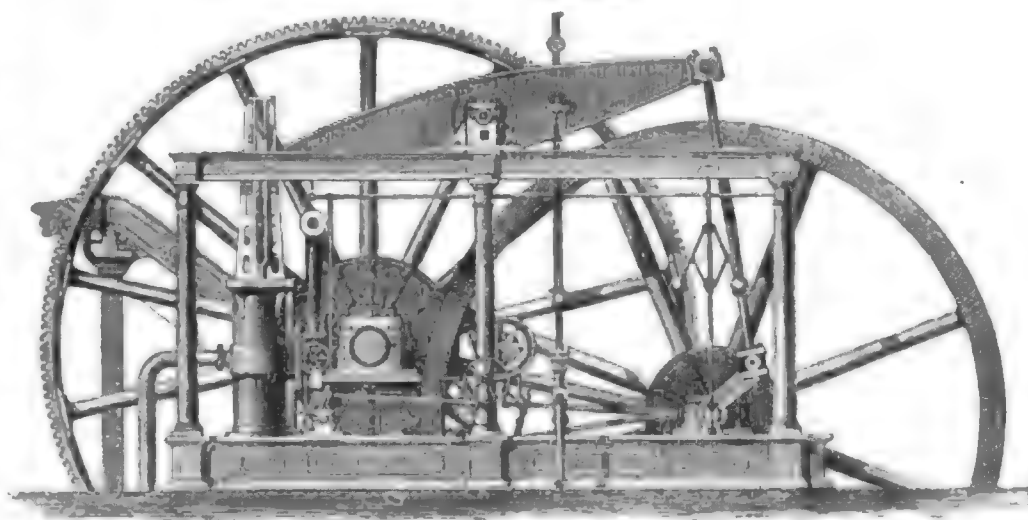


4-HORSE-POWER SUGAR-MILL (to be worked by cattle), by Messrs. W. & A. M'Onie.

and gearing and connections for being driven by bullocks or mules. This sort of mill is used on the smaller and younger sugar-growing colonies, also in the hilly districts of South America, and in Egypt, the East Indies, and the Pacific Islands, where the nature of the country offers obstacles to the transport of heavy machinery, or where steam or water-power is not available (fig. 242).

Messrs. Fawcett, Preston, & Co., of Liverpool, exhibited a *sugar-mill* of an old pattern, with 32-inch rollers 7 feet long, double-gearing as 19 to 1, and a 20-inch steam cylinder with a 4-foot stroke, making forty-five revolutions per minute. The mill is made

FIGS. 243.

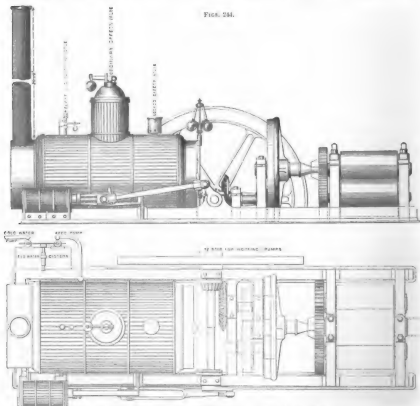


NON-CONDENSING STEAM-ENGINE AND SUGAR-MILL, by Messrs. Fawcett, Preston, & Co., Liverpool. (This mill is different from what was exhibited.)

with solid cast cheeks, which, being in one piece, are not liable to breakage, like others pieced together. But they are unhandy when a roller breaks, as it cannot be taken out without unfixing the cheeks. This is a great practical objection; but the solid cheek is much the cheaper (figs. 243, page 261).

Messrs. John C. Wilson & Co., London, exhibited a small *portable steam cane-mill*, the chief novelty in which is, that the whole of the machinery and the boiler are placed on one base-plate, an arrangement which is facilitated

by the smallness of the proportions. The rollers are only 18 inches in diameter and 2 feet long, and can produce 1 ton of sugar per day. The boiler is of the locomotive type, with an iron chimney, and is placed on one end of the base-plate; the steam cylinder is placed horizontally alongside the boiler, and is connected directly to the crank-shaft at the middle of the base-plate, from which, by means of bevil-gear, the power is transmitted to the rollers, which are placed at the other end of the base-plate. The arrangement is simple and compact, and is



PORTABLE STEAM CANE-MILL, by Messrs. John C. Wilson & Co., London.

suitable for small sizes of mills; but the substitution of bevil for the ordinary spur gear is objectionable (figs. 244).

Messrs. J. F. Cail & Co., Paris, exhibited a *sugar-mill* of the ordinary arrangement, with the exception of the steam-engine, which is horizontal. The rollers are 31 inches in diameter and 5 feet long. The engine has an 18-inch cylinder, with a 40-inch stroke, and is fitted with

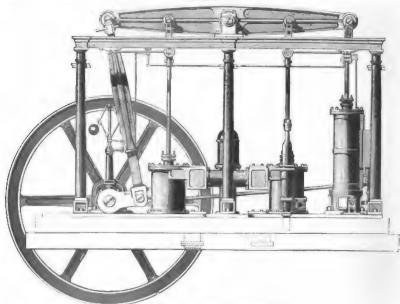
a link-motion for reversing, which is good. The three foundations are on different levels; but one general level, for the engine, gearing, and mill, as in the English mills, is much more convenient. This mill is rather complicated in its forms and details; but in its distinguishing feature, the horizontal engine, it is no doubt more conveniently put together or taken to pieces than the usual beam-engine.



creating and maintaining a vacuum in the sugar-boiling pans. There are two single-acting vacuum-pumps, 18 inches in diameter, and 18 inches

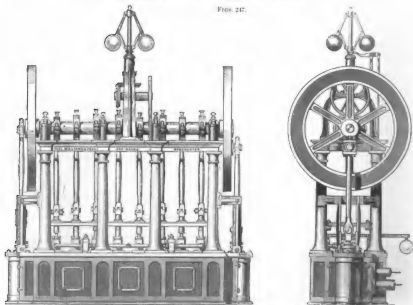
stroke, worked from the beam; and a cold-water pump for the uses of the factory (fig. 246). 2. *A set of Steam Hydraulic Pumps and a Hydraulic*

FIG. 246.



VACUUM-ENGINE, by Messrs. Peel, Williams, & Peel, Manchester.

FIG. 247.



STEAM HYDRAULIC PUMPS, by Messrs Peel, Williams, & Peel.

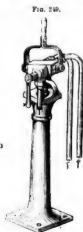
Press for extracting by pressure the saccharine matter from beetroot, which is collected in a groove running round the table of the press. The table is 2 feet 4 inches square, with a 12-inch ram, having 20 inches rise, capable of communicating a pressure of 340 tons. There are eight pumps to work the press, four of which are 1½ inch in diameter, and the other four 1 inch in diameter, with a working stroke of 3 inches. An important contrivance is fitted to the pumps, consisting of a self-acting and self-adjusting relieving apparatus, by means of which the larger pumps are thrown out of action when a certain pressure, variable at pleasure, is attained, and the final squeeze is given by the smaller pumps. The pumps are ranged in a cistern about 8 feet long, and worked by eccentrics from a longitudinal shaft overhead, driven by a pair of vertical steam-engines, one at each end of the shaft, having 8-inch cylinders, with 14-inch stroke, and making 80 revolutions per minute. The cylinders are bolted to the cistern, and the whole apparatus stands together upon a simple foundation (figs. 247, 248). 3. *A Stop or Let-off Equilibrium Valve*, a convenient adjunct to the press. Being balanced, it is easy in motion, and may be placed conveniently near to the press, whilst the pumps may be placed anywhere else (fig. 249).

Messrs. Fawcett, Preston, & Co., Liverpool, exhibited *Aspinall's open evaporating pan*, which contains within it a steam-chest fitted with vertical tubes, immersed in the syrup which freely circulates through the tubes. The pan is used with the ordinary train of open pans, for completing the boiling of the syrup, without the use of vacuum-pans. It works to the best

it. But there is an objection to this pan, that the heat is applied above a quiescent body of syrup in the bottom of the pan, which is about



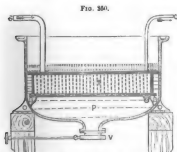
HYDRAULIC PRESS, by Messrs. Peel, Williams, & Peel.



STOP, OR LET-OFF VALVE, by Messrs. Peel, Williams, & Peel.

8 inches deep, and can only reach it indirectly, unless it be stirred, which is not easily done (fig. 250).

Messrs. D. Cook & Co., Glasgow, exhibited the "*Bour pan*," named after the inventor,—an open evaporating pan, for finishing the syrup from the open train, instead of vacuum-pans. It has been for some time in operation in the colonies. It consists of ten hollow discs of copper 3 feet in diameter, on an axis through which the steam for drying the syrup passes freely into communication with all the discs. A number of small buckets are attached on the circumference of the discs, to lift and spread the liquor on the exposed surfaces of the discs as they revolve, and thus accelerate the evaporation. By means of curved pipes inside, the condensed steam is elevated and discharged through the central pipe. With the aid of the Bour-pan, the number of pans in the battery may be reduced, in some cases, to three in number, the finishing being effected by the Bour-pan. The liquor is delivered to it at 20° Beaumé, and may be concentrated, without the risk of carbonizing or browning, at a temperature in the Bour-pan not exceeding 170° Fahrenheit; whereas, in the open pan, the finishing must be done at the boiling-point of the liquor, which is about 235°, producing the ordinary Muscovado sugar. The Bour-pan makes from ten to twenty revolutions per minute; and when steam is plentiful, good sugar can be made at the quicker speed, and more rapidly. It is reported from Penang, that one of these pans has cooked 12 cwt. of sugar per hour, or 6 tons



ASPINALL'S OPEN EVAPORATING PAN, by Messrs. Fawcett, Preston, & Co., Liverpool.

advantage when supplied with liquor from the open train at from 20° to 30° Beaumé. It is reported to be capable of delivering, in less time, twice the quantity of sugar usually delivered from the common train, when used in conjunction with

a day, from 20° Beaumé. Ordinary exhaust steam is employed; and the pans are made with riveted joints to withstand a maximum pressure of 8 lb. per inch. The Bour-pan appears to be the most efficient substitute for the costly vacuum-pan.

Messrs. Manlove, Alliott, & Co., Nottingham, exhibited a pair of *centrifugal drying machines* for sugar, 40 inches in diameter, and capable of delivering 5 tons of sugar per day. They work at from 800 to 1,200 revolutions per minute. The specific duty of the machine is to separate the molasses from the crystals of sugar, the operation occupying from two to ten minutes. The revolving cylinder is constructed of sheet copper, with perforations less than $\frac{1}{16}$ inch in diameter. The machines are driven by a pair of horizontal steam-engines, having the cylinders placed end to end on one base; and the driving-gear being placed entirely below the machine, the space above is left free for operation. Clothes-drying machines on the same principle were exhibited by the same firm.

Messrs. David Napier & Son, London, exhibited a novel *centrifugal drying machine* for sugar, continuously self-feeding and discharging. It is very ingenious and very delicately contrived, but there are 130 valves in the circumference of the machine, for the discharge of the sugar, to be kept in order.

Foreign Machinery.—Messrs. J. F. Cail & Co., Paris, exhibited a system of *vacuum-pan apparatus*, of “triple effet,” with air-pumps; also four excellently-made copper coils. 2. *A Centrifugal Machine*, 30 inches in diameter, driven from above, and coupled by means of bevil friction-cones, on the upright spindle. One of the cones is coated with leather, for the sake of adhesion; it is easily slid out of gear, and a brake is applied to stop the revolving-pan. The open gearing in this pan is objectionable, as it stands in the way of operations.

M. Legal, Nantes, exhibited a model of a *vacuum-pan*, in which a new and good form of save-all is employed. The vapour enters through the side of the save-all—a long, upright, cylindrical vessel,—and the exhaust-pipe going to the vacuum-pump, leaves the save-all at its upper end, and not, as is usual, at the side directly opposite the delivery from the pan. Thus, any liability of the vapour to pass over prematurely to the exhaust-pipe is avoided.

MM. Cail, Hulot, & Co., Brussels, exhibited a set of *vacuum-pan apparatus*, with a horizontal air-pump and cylinder on one base, connected by one piston-rod; also a *centrifugal machine*.

M. Heckmann, Berlin, exhibited a most elaborate *vacuum-pan*, of good workmanship, with four coils, having four inlets and four outlets, with try-cocks on the latter to test the supply of steam.

M. Kronig, Vienna exhibited *sugar-moulds of papier-mâché*, which are free from the objections

to sheet-iron moulds, which corrode by rusting, and frequently stain the loaves, and sometimes resist the removal of the loaves entire. Papier-mâché moulds are expected by the exhibitor to last in good condition for twenty years.

CHAPTER III.

OIL-MILL MACHINERY.

The means adopted for extracting oil, in the last century, by the natives of Ceylon, where cocoa-nuts and other seeds abound, were of the most primitive description. The apparatus consisted simply of a few poles stuck in the ground, supporting two parallel horizontal bars, between which a bag was placed, containing the seed or pulp of the cocoa-nut from which the oil was to be expressed. A lever was then brought to bear against one or both of the horizontal bars, for the purpose of bringing them together, and thereby causing the required pressure upon the seed. The pestle and mortar was also used for the same purpose. The more approved and modern presses are three in number,—the Dutch or stamper press, which was invented in Holland; and the screw press, and the hydraulic press, both invented in England.

The treatment of seed for the extraction of oil consists of five operations. The seed is first passed through a flat screen or shaker, which is kept in a constant state of agitation; secondly, it is passed through a pair of bruising or crushing rollers, and then ground under a pair of edge stones, after which it is heated in the heating kettle. From the kettle the seed is filled into canvas bags; these bags are placed separately between what are called the hairs, which are bags made of horsehair, with an external covering of leather. The final operation of expressing the oil is done in the press by either of the three modes already mentioned. But the hydraulic press is the most approved apparatus for the purpose.

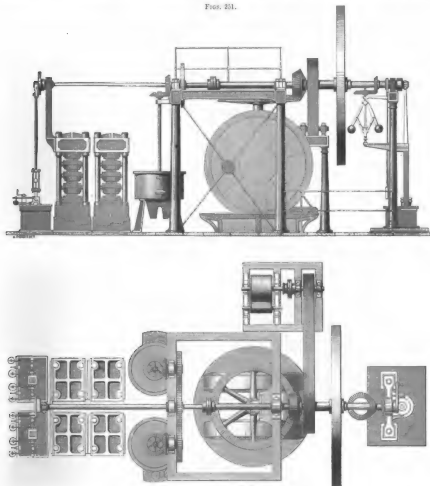
Messrs. Martin Samuelson & Co., Hull, exhibited an *oil-mill* at work, in the manufacture of linseed oil. The whole of the machinery was driven from one main shaft, turned by a vertical steam-engine at one end. The preliminary process of shaking was dispensed with, and the raw linseed, from St. Petersburg, weighing 52 lb. per bushel, was in the first place passed through a pair of metal rollers 22 inches in diameter and 18 inches long, which are capable of rolling or crushing flat three quarters of seed per hour. For grinding, two stones are employed, of Derbyshire freestone, $7\frac{1}{2}$ feet in diameter and 16 inches thick, bevilled off at the edges to 12 inches broad, and weighing 5 tons each; they run on a stone bed, with an iron

rim or trough, which revolves and turns the stones on their axes, and round the vertical axis of the trough.

In the next or heating process, the kettles into which the seed is placed are constructed with steam-jackets or casings, from which they and their contents are heated to 90°, the seed being stirred by blades revolving on vertical axes.

The bags into which the seed is measured from the kettles, hold 10 lb. of seed each, the horsehair wrappers in which they are deposited being 2½ feet long. They are next placed in tiers of four bags each, in four hydraulic presses, making in all sixteen bags. The presses, which are known as Blundell's double hydraulic presses, are worked in separate pairs, with two distinct double

FIGS. 231.



OIL-MILL, by Messrs. Martin Samuelson & Co., Hull.

pumps to work them. The press-rams or cylinders are 12 inches in diameter, with a lift of 15 inches. The stroke of each double pump is 5 inches, and they make thirty-six strokes per minute. The larger and smaller plungers are respectively 2½ inches and 1 inch in diameter;

they are weighted respectively to 740 lb. and 5,540 lb. per square inch, and are both connected to each press cylinder by means of tubing. The first 12 inches of lift are quickly performed while all the pumps are in action; till, when the pressure amounts to a total of about 40 tons

on each press, the larger pumps cease to operate, and the remaining 3 inches of lift are performed by the smaller pumps, which finally exert a pressure amounting to 300 tons on the cylinder. This extreme pressure is allowed to remain in force for about seven minutes from the time the smaller pumps are put in action. The oil passes away by channels into the "spell tank," which is just large enough to hold the produce of one day's operations. The oil is pumped from the

spell tank into larger tanks, capable of holding from 25 to 100 tons of oil, where it remains for some time to settle.

The oil-mill exhibited is capable of crushing about 32 quarters of linseed per day of twelve hours. It produces from that seed from 4½ to 5 tons of oil-cake, and about 2 tons of oil. The total weight of the machinery is from 50 to 60 tons (figs. 251, page 267).

SECTION VII.

MACHINES FOR WORKING IN FLOUR.

CHAPTER I.

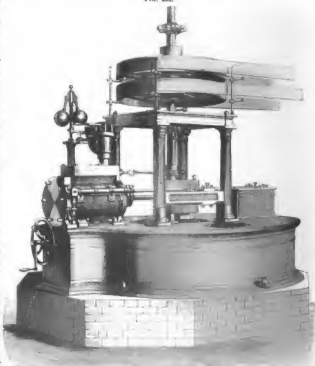
FLOUR MACHINERY.

Several portable grinding-mills for corn were exhibited in the Agricultural Department in the Eastern Annex, adapted for the simple operations of grinding.

Messrs. Whitmore & Sons, Wickham Market, exhibited, in the Western Annex, a novel and compact arrangement of steam-engine, and two pairs of stones for grinding, with independent iron hurst and fittings. The novelty consists in the means for driving the stones direct by belts from pulleys on the upright shaft of a horizontal steam-engine, instead of by gearing from a main shaft. Though silent and steady at work, this motion must throw a considerable lateral strain on the bearings. The meal is discharged equally around the entire peripheries of the stones into metal or wood reservoirs within iron cylinders, in which the bed-stones are supported and readily adjusted. The stones are of French burr, 48 inches in diameter, and they are capable of grinding from ten to twelve bushels of corn per hour. Tighten-

ing pulleys are provided for taking up the slack of the driving bands. The free discharge of the meal round the stones prevents its being heated by them. The stones are balanced on Clarke & Dunham's system, by which the balance is preserved whether at rest or in motion. The

FIG. 252.



STEAM-ENGINE FOR FLOUR-MILLS, by Messrs. Whitmore & Sons, Wickham Market.

engine is of ten-horse power, with a horizontal cylinder; the fly-wheel is neatly encased within the base of the engine; the driving shaft is of

centre, the flour is expelled from the stones as soon as it is produced, and thus a greater quantity and better quality, according to the experiments of the exhibitor, are obtained with the same motive-power: the flour is removed without being heated by needless friction, and power is saved.

Messrs. Bryan Corcoran & Co., London, exhibited, besides ordinary flour machinery, a *French burr stone* 5 feet 8 inches in diameter, in one piece. As a curiosity, the stone was unequalled, but it is of questionable utility, as so large a piece may contain parts of various degrees of hardness. The usual method of forming grindstones is to assort the pieces of equal degrees of hardness, and join them together.

Mr. John Hill, Ashford, exhibited a *flour-dressing machine* with a revolving cylinder, which is turned by a worm and screw motion at the lower end, instead of the longitudinal bars usually placed across the ribs. The cylinder is cleaned by an exterior brush, which extends the whole length of the cylinder, and is worked so as to give a rubbing motion like that of the hand. Stirrers are attached to the feed-roll to prevent the meal about to be dressed from clogging above the roll. This machine dresses about fifteen sacks of flour per hour, as against six sacks per hour, which is the usual performance with the old stationary cylinder.

M. Mauzaize, Chartres, exhibited a friction coupling for mill-stone spindles, by friction-cones, to engage or disengage "instantaneously without shock."

CHAPTER II.

BREAD-MAKING MACHINERY.

To convert the dressed flour into bread, it requires to be mixed with water, salt, and carbonic acid, forming a homogeneous mass, which is baked in the oven, where it swells by fermentation and acquires that uniform spongy porosity which is important for easy digestion. The process of making bread has heretofore been done by hand labour, the disadvantages of which are sufficiently well known. The

FIG. 253.



Flour-Mill, by Messrs. Whitmore & Sons.

wrought-iron, steeled at the lower end, and revolving in a steel step. The piston-rod is compactly connected to the crank on the "steepie" plan, upon the cast-iron base enclosing the fly-wheel (figs. 252, 253).

Mr. Thomas Neal, London, exhibited a *grinding-mill*, of which the novelty consists in driving the bed or lower stone,—not the upper one as is usually done,—the upper stone being fixed in the frame. A pair of small stones, 18 inches diameter, will grind three bushels per hour. For small sizes this system is likely to prove advantageous in grinding a greater quantity of corn with the same expenditure of power.

M. Buisson, Tullins (Isère), exhibited a similar *mill*, in which the under stone is made the runner. By a forced current of air, introduced at the

fermentation is caused, in the ordinary process, by yeast or leaven, which being intimately mixed with the flour is brought into contact with every particle of starch, and being submitted to a convenient temperature produces minute bubbles of carbonic acid, making the mass spongy and light. If the leaven be not thoroughly incorporated, the bubbles, not being surrounded by a coat of gluten, collect together and form large ones, to the detriment of the dough. The mixing of the yeast is executed by two stages: first, only a portion of the flour is employed to make the "sponge," and there is no great difficulty in it, because the mass is then rather soft. The mixing of the sponge with the remaining flour, the kneading process, is a much more difficult operation, the carbonic acid being produced by the decomposition of a certain quantity of the starch contained in the flour. But the new system of bread-making on Dr. Daughlish's system does away with all chemical changes in the flour; and, the necessary supply of carbonic acid gas having been obtained independently of the flour, the gas and the flour are mixed by mechanical means, insuring a constant supply of elastic dough and a light spongy bread. Thus the waste of flour is prevented, immediate manual labour superseded, and the time required to convert flour into baked bread is reduced from at least ten to two hours.

Messrs. Barrett, Exall, & Andrewes, Reading, exhibited, in the Agricultural Department, the *aërated bread machinery* of Dr. Daughlish. Ingeniously availing himself of the capacity of water for absorbing great quantities of carbonic acid, Dr. Daughlish preserves the flour in its natural state, and supplies carbonic acid otherwise than by fermentation at a very cheap rate. This gas, easily obtained perfectly pure, is forced into the water, which is placed in a strong vessel, at a pressure of ten atmospheres, and is retained by this water so long as it remains under the same pressure. The flour and salt are placed also in a close vessel capable of bearing the same pressure, within which is fitted a kneading apparatus worked from without. The water is made to pass, under pressure, from the first into the second vessel. The kneading apparatus is set to work at the same time, and thus in half an hour the elements are intimately mixed before imparting to the mass any vesicular property, as every atom of water holds its own quantity of gas. When the kneading is completed, a valve is opened in the bottom of the vessel through which the dough is forced by the internal pressure. The gas being thus released from the pressure, is extricated in bubbles from each particle of water, and makes the dough thoroughly spongy and ready to be drawn and shaped into loaves, and to be baked immediately.

The supply of carbonic acid gas is obtained chemically from sulphuric acid and chalk (car-

bonate of lime), by means similar to those employed by the manufacturers of aërated waters. The sulphuric acid is contained in a leaden vessel fitted with a plunger, worked by a screw driven by the engine, and is supplied at a fixed rate to the generator, where it meets with the chalk and is well mixed with it by means of an agitator. The carbonic acid thus generated is delivered into a reservoir of sheet brass, suspended in a large vat of water, like an ordinary gas-holder, from which it is conveyed by pipes to the mixer. The whole of the mixing machinery—comprising the steam-cylinder, the mixer, the gas and the vacuum pumps, and their respective crank and other connections—is supported on two cast-iron side-frames. The mixer is of cast-iron, and of an elliptical form; it is traversed by a horizontal revolving spindle, which carries the knives and scrapers, and is driven by toothed gearing on the outside. The flour and salt are admitted through an opening in the top, which is closed by a door with leather packing. Two small cocks are applied at the bottom of the mixer to draw off the saturated dough. The condenser, made of copper, is suspended above the mixer, and carries a gauge glass to indicate the level of the water within it. The vacuum-pump is a trunk pump, of cast-iron, with a cast-iron plunger, packed with leather and a brass ring; it has a brass inlet-valve communicating by a pipe with the mixer, and an outlet valve with a two-way cock, to discharge into the atmosphere or—if it be drawing superfluous fixed air from the mixer—into the reservoir. The carbonic acid pumps consist of two connected barrels of cast-iron, lined with brass, and fitted with brass plungers; they draw gas from the reservoir, and force it into the mixer.

The process of manufacture is described by the exhibitors as follows:—The various cocks communicating between the mixer, the pumps, and the condenser, are rightly adjusted, as well as the dough-nozzles at the bottom of the mixer. The door at the top being opened, the flour and salt are shot in, the leather packing round the hole swept clean, and the door screwed hard down, so that the joint is air-tight. Meanwhile, from a cistern above, water has been flowing into the condenser, being, however, prevented from continuing its way into the mixer by the stop-cock. When sufficient water is in the condenser, as indicated by the gauge-glass, the supply is shut off, and the cocks communicating from the vacuum-pump to the condenser and mixer are opened. The pump is then worked until a vacuum of about 13 lb. per square inch is obtained, when it is stopped and its communicating cocks shut, and those of the carbonic-acid pumps opened. These are then worked, drawing the fixed air from a reservoir, and forcing it through the water in the condenser into the mixer, until a pressure of 90 lb. on the square inch is obtained,

when they are stopped. The water in the condenser, which now is, in fact, first-class soda-water, is permitted to flow into the mixer upon the flour and salt already there, and the mixing knives then commence operations; these, which are so arranged as to completely mix every particle of flour and water in the mixer, are driven for ten minutes. At the end of that time the dough is ready to be drawn off. This is accomplished by merely opening one of the dough-nozzles, as the high pressure within immediately forces the dough through the open aperture. A workman with a small box of the right size in the one hand, and a knife in the other, stands ready to receive the dough as it issues from the nozzle. When his eye tells him sufficient is in the box, he slips off the dough close to the nozzle with the knife, and passes the box to a man at the weighing machine, who stands beside him; he, with a knife and fork, adds to or subtracts from the amount in the box, as the scales indicate to be necessary. The box is then placed on a tray with others, and carried to the oven-door. Here stands the baker, who, taking the boxes one by one, turns the contents out upon his peel, and deposits them in the oven. When baked, the loaves are drawn forth and carried where necessary, being then, for the first time during the whole process, touched by the hands. The average time occupied by the process, between the shooting of the flour into the mixer and the drawing of the loaves from the oven, is about two hours, and the number of loaves made by an ordinary-sized mixer, about 225 quarterns. When the dough is all drawn, the abstracting cock is shut, and the remaining fixed air in the mixer, which has now become reduced in pressure to about 60 lb. per square inch, is drawn off by the vacuum-pump and discharged into the reservoir. The apparatus is now ready for the manufacture of another batch.

The prime importance of the effective introduction of machinery for the manufacture of bread must be acknowledged by all; and the world is indebted to Dr. Dauglish for the perseverance and ingenuity of resource he has displayed in following up the manufacture to a successful issue. In large bakeries the process will prove a most valuable one for promoting economy and rapidity of production in combination with a good and wholesome quality. There is one point not yet considered, in which Dr. Dauglish's system is the only one capable of effecting an important improvement. M. Mourié proposed, some years ago, to utilize a nutritious substance commonly thrown away with the bran—a nitrogenous body analogous to gluten—which the discoverer named *cerealine*, with a portion of another well-known nitrogenous body—vegetable caseine. This substance has a powerful solvent action, promotes the easy and healthy digestion of gluten and starch, is the solvent prepared by nature for their assimilation, and has been long known to be exceedingly rich in plastic and

tissue-forming elements. But there is a drawback in using it in the ordinary manner; it alters the gluten during the fermentation of the sponge, and gives to the altered matter a brown colour. But by Dr. Dauglish's process, as fermentation does not take place at all, bread made from flour mixed with *cerealine* is quite free from the brown tint.

CHAPTER III.

KNEADING MACHINES.

In small bakeries, where Dr. Dauglish's baking machinery would be too costly, machines may be economically and advantageously substituted for manual labour in the process of kneading, whilst the ordinary process could be followed in making the sponge to be fermented by the yeast. Dough kneaded by machine is turned out perfectly clean, and is more intimately mixed than when done by hand labour. It is also done in less time, and shortens the hours of labour; and whilst the bread is rendered more easily digestible, the inhaling of flour-dust and carbonic acid from the mixture is avoided. In kneading by machine, the manual labour is much less than in kneading by hands and arms, and the kneading-trough being closed, there is no waste of flour. In hand-made bread, thousands of small particles of flour that have never been wetted at all are discoverable by the aid of the microscope; while in the machine-made bread, every particle is found to have been brought into contact with the liquid. Thus the machine causes the flour to take up more water, which is no more than what is properly due to the quality of the flour; and the proof is that the loaf of machine-made bread retains its weight after standing twelve hours, just as the hand-kneaded bread does. These economical advantages amount to a saving of nearly three per cent. in flour only.

Mr. E. Stevens, London, exhibited his *dough-making machines*, worked with revolving blades, which appear to have been extensively employed in Government as well as in private establishments. Mr. Stevens thus summarises the advantages of machine-mixed bread as compared with that kneaded by hand:—It is purer and more cleanly made, whiter, lighter, moister, less liable to crumble, less liable to sourness, keeps better, cuts finer, eats better, is more digestible and wholesome, sooner baked, thinner crusted, sweeter tasted, and cheaper; 12 lb. more bread is produced from each sack of flour. The machine has a double bottom for containing water, which may be poured in hot, or a jet of gas may be laid on and lighted when required, to regulate and force the sponges or the doughs,

so avoiding the necessity of using so much hot water, which is injurious to the bread.

Messrs. T. & T. Vicars & Co., Liverpool, exhibited a *kneading machine*, consisting of two vertical shafts, carrying radial arms, which pass each other in opposite directions, and are arranged spirally, so that in addition to a tearing action on the dough which the knives exert in passing each other, they have a screwing action, pressing the dough downwards on the one side, and carrying it up on the other. The vessels containing the dough are made of wood, of an oval form, to correspond with the action of the machine. The mode of operation is described as follows:—The materials for the sponge—that is, flour, yeast, salt, and water—are placed in the vessel, which is then placed under the machine for about five minutes, by which time the sponge is thoroughly mixed. The vessel is then removed, and after six or eight hours' fermentation of the sponge, it is again brought under the machine, and the flour and water requisite are added, when the machine in about six or seven minutes works it into dough. It then remains two or three hours to prove, by which time the whole mass is in a state of active fermentation, and is then ready for the oven.

Mr. H. Goodall, Derby, exhibited a small *domestic kneader*, worked, like his grinding machines, by means of a pestle working in a tin bowl, the action of which has already been described at page 247.

M. Lesobre, Paris, exhibited *Rolland's kneading machine*, consisting of a semi-cylindrical trough and a horizontal shaft placed inside, with curved blades, alternately long and short, forming two perpendicular rows if the dough to be kneaded is soft, or disposed in two helical rows if the dough is of the ordinary toughness. The shaft is put in motion by a spur-wheel gearing with a fly-wheel and a handle. This machine is adapted for setting sponge as well as for making dough. It is stated that a sack of flour (six bushels) is converted into dough in a quarter of an hour.

M. Boland, Paris, exhibited a *machine* of the same kind as M. Lesobre's, with propelling power at both ends of the shaft.

M. Drouot, Paris, exhibited a *machine* consisting of an annular trough, driven around a central column supporting the mechanism for moving the trough, the helical blades working horizontally, and the vertical mixer. The vertical mixer, which is a peculiar feature of the machine, moves at right angles with the blades, imitating by the cross action the approved method of hand-labour, in which the partially-kneaded dough is cut in pieces, to be kneaded in another direction. Every portion of the dough is brought in succession under the action of the blades and the mixer by the circular movement of the trough. The heat of the oven is economically employed to make steam for the engine by which the machine is driven.

CHAPTER IV.

BREAD-BAKING APPARATUS.

M. Drouot, as already stated, economises the waste heat of the oven to raise steam for working the machine.

Messrs. T. & T. Vicars, Liverpool, exhibited a *travelling or railway oven* for baking bread, on the principle of the oven for several years successfully employed by them in baking biscuits, to be afterwards described. But although the ovens were thoroughly efficient for baking biscuits, requiring at most 20 or 30 minutes to bake, and never exceeding an inch in thickness, the case was altogether different when they came to deal with a loaf frequently nine or ten inches thick, and requiring two hours or more to thoroughly bake it. In baking biscuits, the retention of the steam given off during the process is not of consequence; but in baking loaves of any size, it is absolutely necessary to get rid of it. The oven for baking bread consists of a tunnel or long chamber, provided with furnaces and flues so arranged as to produce the baking temperature, these furnaces and flues being under perfect control by means of register doors and dampers. The chamber is also provided with fixed pyrometers, indicating the temperature at all times. An endless chain works through the chamber, connected with mechanical arrangements for adjusting its speed. The loaves to be baked are placed in tile-bottomed waggons. Each waggon is provided with a steam-tight cover, which covers the bread somewhat after the fashion of a dish-cover, rendering it steam-tight, and making each waggon a perfect oven in itself. The chamber may be made of any desired length to adapt it for receiving the necessary number of waggons; its capacity may be increased to any reasonable amount, adapting it to the requirements of a trade however large. The mode of working is this:—At one end of the chamber the waggons are being constantly filled with bread. They then travel at a regulated speed through the chamber and by the time they arrive at the opposite end they are baked. The foreman regulates the temperature of the chamber and the rate of travel, over both of which he has perfect control. The empty waggons are returned through an upper chamber, which is kept of pretty high temperature by the heat of the lower chamber. Thus the process may go on without interruption the whole day.

M. Lesobre, Paris, exhibited *Rolland's revolving oven*, which is of a circular form, with a revolving floor like a turntable. It is heated by a distinct furnace, from which the hot products of combustion circulate in iron pipes around the enclosure reserved to the loaves, and within a double metal roof. The floor is turned by a handle, and the loaves are

deposited successively on the vacant space turned towards the mouth of the oven. The heat is uniformly distributed without loss; the baking is regular and continuous, and there is no contact with ashes.

CHAPTER V.

BISCUIT MACHINERY.

Messrs. Barrett, Exall, & Andrewes exhibited an excellent series of *biscuit machinery*. A revolving mixer consists of a moveable pan revolving horizontally, in which a heavy grooved roller works. The dough is kneaded by another machine provided with rollers; by means of other rollers the sheet of dough is reduced to the exact thickness required for the biscuits. By a third machine the edges of the biscuits are shaped and trimmed.

Messrs. Porter, Hinde, & Porter, Carlisle, exhibited a *machine for making biscuits*, to be remarked for the method of effectively separating the biscuits from the scrap, and placing them on the baking trays. For the smaller sizes of biscuit, 3,000 pieces are rolled and cut per minute. The dough is forced by hydraulic pressure through a drawing plate, provided with several holes of the desired shape, and is cut off into suitable lengths by a knife.

Messrs T. & T. Vicars, Liverpool, exhibited their *travelling oven for biscuits*, already referred to. It is 32 feet long, and 8 feet wide, and consists of an endless chain of sheet-iron plates, 8 feet wide, revolving on two iron rollers, situated one at each end of the oven. The unbaked material is arranged on the front plates, which take from 15 to 20 minutes to reach the other end of the oven, whence the biscuits which have been baked during the interval drop out into baskets prepared for their reception. The time which may be deemed necessary to keep the biscuit inside the oven, is regulated by means of a crank and ratchet placed outside.

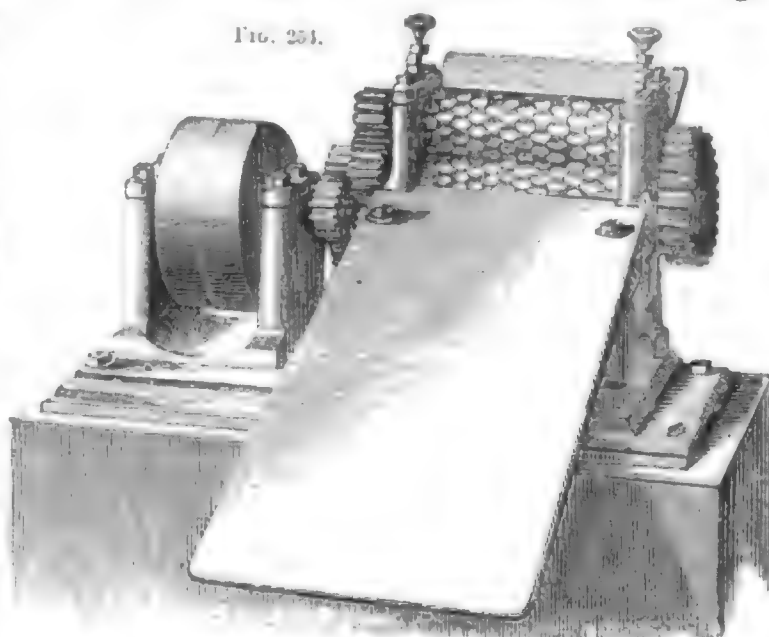
CHAPTER VI.

CONFECTIONERS' MACHINES.

Mr. Luke Collier, Rochdale, exhibited a series of *confectioners' machines*, for making jujubes, marmalade, and acid and other drops.

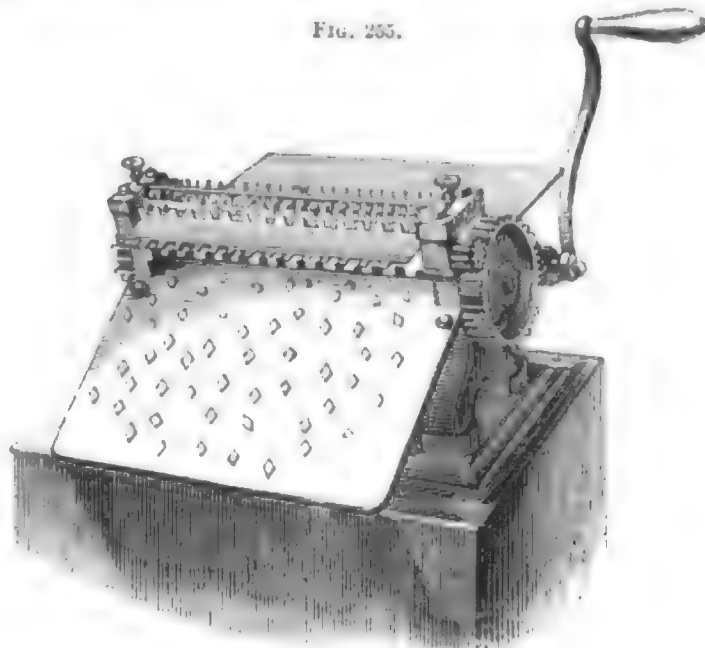
Also a small *biscuit-rolling machine*, and a *sugar-grinding mill*. In working the jujube-cutting machine, a sheet of gum, 15 inches wide, is fed in the usual way, and is cut into strips, of the width of a jujube, by a series of circular knives, 28 in number. The strips are again passed through the rollers, and cut into diamond shapes. With the marmalade machine, three boys can cut 8,000 oranges by hand, or 12,000 oranges by steam-power. In the acid-drop machine, two rollers, geared together, have their surfaces formed into dies or matrices, in halves, within which, when a sheet of the stuff is passed, the drops are formed. The sugar-

FIG. 254.



MACHINE FOR MAKING ACID, AND OTHER DROPS, by Mr. Luke Collier, Rochdale.

FIG. 255.



JUJUBE-CUTTING MACHINE, by Mr. Luke Collier.

grinding mill is arranged like a coffee-mill, and grinds by hand 30 lb. of loaf-sugar per hour, suitable for lozenges; or, by steam, 5 cwt. per day (figs. 254, 255).

Mr. H. Weatherley also exhibited a number of confectioners' machines.

Mr. John Casson, Woolwich, exhibited *raisin and currant-dressing machines*. The fruit to be dressed is placed in a wire-net cylinder, with loops or catches fixed on the inside, by which, when the cylinder revolves, the masses of fruit are broken up, and the stems are separated. The cylinder is cleaned by a brush applied

longitudinally to it, on the outside. The raisin-machine, having a cylinder 22 inches in diameter and 28 inches long, is said to be capable of dressing and stripping 56 lb. of raisins in ten minutes; and a 16-inch cylinder will dress and strip 20 lb. of currants or sultanas in three minutes.

SECTION VIII.

MACHINES AND APPARATUS FOR WORKING IN WATER, AND BREWING.

CHAPTER I.

THE PURIFICATION OF WATER.

Water, in its natural state, is never absolutely pure, but contains organic or inorganic matter, or both, in suspension or in solution, or partly in both conditions. Organic matter, if undecomposed, or, on the contrary, thoroughly transformed into new productions—in the forms of microscopical plants or animals,—is generally harmless, but when in the transitional stage, of putrefaction, it is injurious to health. Inorganic matters, with metallic bases, are unwholesome or even dangerous to health; but those based on earths or alkalis are harmless. Matters which prove inconvenient for some household purposes, and for manufacturing processes, are chiefly the earthy salts, which render water hard, and alkalis, which affect colours; organic matters and some metallic solutions impart colour.

All these foreign matters, in solution or in suspension, can be removed by artificial means,—that is to say, by distillation, by filtration, or by precipitation or subsidence. Distillation removes every foreign matter from the water, whether it be present in solution, or in suspension, or in both states; filtration removes matters in suspension, and some matters in solution; whilst precipitation and subsidence only remove matters in suspension.

CHAPTER II.

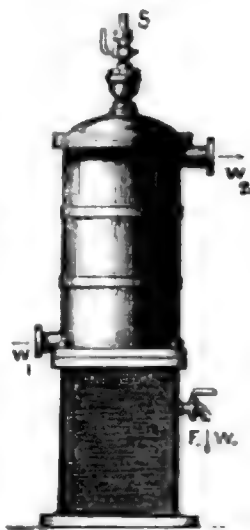
WATER-DISTILLING APPARATUS.

The ordinary plans for producing fresh water from salt water merely proceed on the principle of the common still, and the distilled water produced by them requires to be aerated by agitation in the tanks, either by the motion of the ship whilst steaming or sailing—a mode of aëration which requires a considerable time,—or more rapidly, but also in a more costly, fatiguing, and cumbrous manner, by artificial means. The result is an imperfectly aerated water, vapid and indigestible, and susceptible of taint.

Messrs. Normandy & Co., London, exhibited their *marine aerated fresh-water apparatus* in operation, for obtaining wholesome fresh water by evaporation from sea-water. The thorough aëration of the water is the distinguishing feature of the apparatus. The water is aerated, at the very moment it is produced, with the super-oxygenated air and carbonic acid naturally contained in water. The water is evaporated by means of steam from a boiler, passed through pipes immersed in the water. The air extricated from the sea-water rises with and is absorbed by the vapour during its condensation; and the water is freed from the empyreumatic odour peculiar to water distilled from heated surfaces, which act on the organic matter usually absorbed by water, by being passed through a charcoal filter.

Messrs. A. Chaplin & Co., Glasgow, exhibited a *ship's engine and apparatus for reinding, cooking, and distilling fresh water*. The distilling apparatus is very simple and compact, consisting of a condenser, with an internal worm-pipe of block-tin, or tinned copper; a circulating pump to supply cold water, and a filter containing charcoal and sand, through which the distilled water is passed twice—downwards, and upwards—after which it is drawn off. To the top of the condenser is fitted a "Chaplin & Russell's distil-aëerator," a novel, simple, and efficient appliance for aerating the distilled water. The aëration is effected by means of a small cup-shaped closed vessel, of brass, having its upper rim perforated with holes. When the steam to be condensed is turned on, the external air is drawn in with the current by suction, and rushes through those openings into the condenser, so as thoroughly to commingle with the steam at the moment of condensation, and fully to aërate the

FIG. 256.



DISTIL-AERATOR, by Messrs. Chaplin & Co., Glasgow. S, entrance for steam; w₁ and w₂, inlet and outlet for condensing water; F.W., fresh water.

water, which is delivered clear, bright and colourless, palatable, and devoid of odour. Its temperature, as it runs from the condenser at the rate of 25 gallons per hour, is about 60°. The proportion of dissolved gases in the water was found by Professor Penny, of Glasgow, to be almost exactly the same as is found in the soft waters used in large towns. The quantity of gases dissolved in the aerated water was found by Mr. A. T. MacHattie, of Glasgow, to range from 6½ to 7 cubic inches per gallon. The engine will be further noticed in its proper place (fig. 256).

CHAPTER III.

FILTERING APPARATUS.

Solid matters in water subside by virtue of their greater specific gravity. The rapidity with which they subside depends partly on the bulk or size of each particle, and on its specific weight. Matters in solution may be made to subside by previously converting them into their original solid state by means of chemical re-agents. Solid matters, and some others in solution,—for instance, decomposing organic matters, and, to a limited extent, metallic oxides and earthy salts,—are also removed by means of filtration. For filtering matter in solution, animal or bone charcoal is found to be the most powerful agent.

It is commonly supposed that, for the purpose of filtering matter in suspension, the pores or crevices of the filtering material must be smaller than the smallest particles to be retained. This notion is, no doubt, true with regard to a sieve, but it does not hold good for a filter; for, in the latter, the large and small solid particles are required to be separated from the fluid ones. Now, particles not larger than one forty-millionth part of a cubic inch, visible only under a powerful microscope, will, if present in quantity, make water turbid; but through pores of so small a size water itself could not pass, except under pressure considerably greater than what is applicable to any filtering apparatus. The power by which the arrested particles are detained whilst the fluid matter passes on, is chiefly that of capillary attraction, which will operate, unless it is counteracted by gravity. If so baffled, of course the impurities, instead of adhering to the sides or projections of the minute channels in the filtering medium, will be carried along with the water, and the water will be imperfectly filtered.

The principal point to be considered in the process of filtration, accordingly, is the speed with which the water is made to flow through the filtering material; and whilst fine-grained filtering material has been tried, though in vain, with the object of producing pores finer

than the finest particles to be arrested, it has, nevertheless, answered the purpose, inasmuch as the water filtered through under a given pressure at the required speed. But there is a drawback to this mode of action; for if the speed be right at the commencement, when the filter is clear of deposit, it must fall off when the pores get clogged or reduced in size by the deposited particles. The filter-beds of the waterworks require to be cleansed, by removing the layer of clogged sand, every three or four weeks, or even more frequently. Domestic filters are often found useless for the same reason.

Messrs. T. H. Danchell & Co., London, exhibited *filtering, water-softening, and water-testing apparatus*. In the filtering apparatus, Mr. Danchell, perceiving the defects of the ordinary systems, employs a coarse-grained filtering material, through which the water can pass very freely, so as not to be very materially checked by the size of the pores or crevices, and he regulates the speed of the current by the inlet or outlet of the water to or from the filter. The advantage of such an arrangement is, that a filter so constructed will pass at least twenty to twenty-five times the quantity of water that can be transmitted by any common filter, before showing any perceptible difference in the quality.

In order not to tax the filter more than is necessary, Messrs Danchell & Co. cause the water to filter by ascension, and thus to leave the impurities that are too heavy to be carried upwards by the current, to subside before reaching the filter. With a size of filter just sufficient to yield the quantity of water required for use at a time, the water is purified when wanted, and the accumulation of fresh impurities after

FIG. 257.



FILTERING APPARATUS, by Messrs. T. H. Danchell & Co., London.

filtration is prevented. By placing the domestic filter in the cistern, the necessity for special attention on the part of domestics is obviated (fig. 257).

M. Nadault de Buffon, Paris, exhibited *tubular filters*, in which the filtering substance consists of mineralised wool-powder, compressed into the space between an external metallic tube, and an internal perforated galvanized iron cylinder. The water is filtered through the wool-powder into the inner cylinder, from which it is drawn off for use. The filter is said by the exhibitor to intercept the salts held in solution, and to be readily cleansed by simply reversing the direction of the current, to flow from the inner cylinder through the powder. The action of the filtering substance in precipitating the salts is not very obvious.

MM. Lorenz & Vette, Berlin, exhibited *reservoir filter balls*, made of "plastic charcoal." They are porous hollow balls, of from 4 to 8 inches in diameter, used by means of a tin or india-rubber syphon-pipe, for rendering bad water drinkable. The filter is immersed in the water to be filtered, and the air is sucked from it, when the water percolates into the interior and flows off pure through the syphon. The ball may be cleansed by reversing the operation, —blowing back the water through the pores.

CHAPTER IV.

PRECIPITATING APPARATUS.

The method of purifying water by means of precipitation, is particularly applicable to water containing lime and magnesia, in the form of bi-carbonates, in solution. These salts may be deprived of a portion of their carbonic acid, and thereby converted into carbonates, which, being insoluble, subside, and leave the water clear. The bi-carbonates render water hard, and, as such, are wasteful for many domestic and manufacturing purposes, whilst they are in other respects inconvenient.

A variety of modes have been proposed for precipitating the lime and magnesia thus held in solution, and to render the water soft; but the method invented by Dr. Clark, in which caustic lime is employed to reduce the bi-carbonates, undoubtedly deserves the preference. The only drawback attending the application of this, as of other plans, is the difficulty of employing it for household purposes, where the management of it is left in the hands of domestics.

Messrs. T. H. Danchell & Co. exhibited a *precipitating apparatus*, embodying Dr. Clark's process, nearly self-acting, requiring no attention beyond the occasional removal of deposits, and the renewal of the precipitating agent. The cistern is divided by a vertical partition into two compartments, a smaller and a larger, in the proportion of one to six, to hold respectively the store of caustic lime and the purified water. The water supply from the service pipe is

delivered into a small receiving chamber fixed over the smaller compartment, from which it is distributed, in fixed proportions, determined according to the degree of hardness of the water, by suitably sized outlets, in two currents—one by a small pipe to the bottom of the lime compartment, whence it ascends through, and dissolves an equivalent of caustic lime; the other current is delivered into a mixing tube placed upright in the larger compartment, where it is met by the lime-water current delivered from the lime compartment. By the intermixture of these currents, the bi-carbonate of lime is reduced by the caustic lime, and the insoluble product, carbonate of lime, or chalk, falls to the bottom of the mixing tube, which, for the purpose of holding the precipitated chalk, is continued down through the bottom of the cistern. The water percolates through the stratum of chalk, and ascends as soft and clear water through a return tube into the cistern.

Messrs. Danchell & Co. exhibited also their *testing apparatus* for discovering the presence of impurities in water. Seven testing fluids are supplied, to test for lime, ammonia, lead, iron, and decomposed organic matter. The tests are made to depend upon the appearance of the water after the addition of one or other of the testing fluids.

M. Durenne, Paris, exhibited *M. Wagner's water-softening apparatus*, called the "hydratmo-purificator," which is worked on the principle that hot water holds less of the salts of lime in solution than cold water; and that, consequently, if the cold water to be purified be sufficiently heated, the greater portion of the salts will be precipitated. A series of hollow trays or platforms are placed one above another in a square case, in which the cold water is introduced at the top, and trickles down from one to another, enveloped in the waste steam of an engine, or steam from a boiler direct. The water, becoming heated, deposits a portion of its salts of lime on each tray until it is discharged at a high temperature, and softened, at the bottom of the chamber. By opening the front of the case, the trays are taken out from time to time, and cleared, or replaced by fresh ones. The apparatus is specially applicable for purifying and heating feed-water for steam-boilers, and it is reported to work efficiently. M. Tresca states that he has seen the results of its application to a portable engine, in which it was placed inside the dome of the boiler. Nearly the whole of the lime was deposited from the water upon the trays, to a thickness of about $\frac{1}{2}$ inch. He mentions that a similar apparatus has been applied in Austria, by M. Schau, to a number of locomotives on the railway from Vienna to New Szönyi, and that by that means seven-tenths of the incrustation which would otherwise have been formed in the boilers, was intercepted by the apparatus. M. Tresca further quotes the results of experiments on the waters of the Seine by

M. Durenne, with Wagner's apparatus, which are rendered in the following table, showing that four-fifths of the impurities were intercepted :—

Impurities in the Water.	Composition of the Water per litre (61·028 inches).		Proportion of Matters precipitated.
	Before entering the Apparatus.	After leaving the Apparatus.	
Bi-carbonate of lime and of magnesia ...	Grains. 17·55	Grains. 2·77	Per cent. 84
Sulphate of lime and of magnesia	9·90	2·46	75
Silica, chlorides, and vegetable matter	0·65	0·38	40
	28·10	5·61	80

CHAPTER V.

ICE-MAKING, FREEZING, AND COOLING MACHINES.

The manufacture of ice is a business of recent origin; it has arisen within the last five years. The principle on which machines for making artificial ice are constructed is an application of the natural law by which the heat contained in evaporating fluids passes off with the vapour, thereby cooling the evaporating body and other bodies in its neighbourhood. The natives of India practised this principle in their so-called ice-pans, or shallow tanks covered with wet straw or rushes, to assist the evaporation; by means of which, it is asserted on good authority, a film of ice was formed during the night. The formation of ice by this means appears to have been disregarded by mechanical men, who considered it merely as an experiment for the laboratory.

Mr. D. Siebe (now Messrs. Siebe Brothers), London, exhibited an *ice-making machine*, invented by Mr. Jacob Perkins in 1834, improved upon by Mr. J. Harrison, of Australia, in 1856, and subsequently improved by Mr. D. Siebe in 1862. A volatile fluid—ether by preference—is placed in an air-tight vessel, and is evaporated *in vacuo*, the vacuum being formed by means of a pump,—which, in its continued efforts to reduce the pressure in the formation of a vacuum, in the first place promotes the evaporation of the fluid at a low temperature; in the second place, by positive compression, the pump, with the cooling aid of water at an ordinary temperature, further reduces or condenses the vapour to the fluid condition from which it was converted. The fluid then flows back to the refrigerator from which it started, and thus, by a continuous circuit, it is alternately evaporated at a low temperature, and condensed by pressure at a higher temperature, with water as a medium, and used over and over again, without any loss of material, except such as may take place by

leakage. The supply of ether to the refrigerator is regulated by a self-acting valve. A temperature 50° below the freezing-point of Fahrenheit's thermometer may be effected; but in place of an unprofitably low temperature, the cooling action is distributed through the mass of salt water employed as the freezing medium, the salt water retaining its fluidity below 32° Fahrenheit, the freezing-point of fresh water. The refrigerator—a long, low trough—is conveniently arranged, so that the ice-moulds can be moved successively towards the coldest portions of the circulating medium, as the frozen moulds are removed, whilst fresh moulds are placed at the further end of the refrigerator. The slabs of ice, as they are taken from the moulds, are piled upon one another, so forming blocks of any size or weight.

Messrs. Carré & Co., Paris, exhibited a *cooling apparatus*, in two forms,—one for domestic uses, to make ices, sherbets, &c.; the other for manufacturing purposes. In these, heat is employed without the aid of a steam-engine. They operate on the general principle, already enunciated, of the absorption of heat by fluids in the course of evaporation; and are based on the fact that water, when cold, absorbs a large quantity of ammoniacal gas, which, when the water is heated, escapes and is condensed in a cold vessel. On the contrary, when the water just heated becomes cold, a vacuum is formed, and excites a rapid evaporation of the ammonia into the vessel of cooled water, to be again absorbed. The heat necessary for the evaporation of the ammonia is extracted from the water surrounding the vessel in which the liquid ammonia is contained, and the water consequently is frozen. The evaporating medium in this, as in the other machine, is used over and over again, without loss, except from leakage.

The household apparatus is convenient also for use in the laboratory. It reduces the temperature to from 40° to 58° Fahrenheit below the freezing-point. One pound of coal produces from 2 lb. to 3 lb. of ice. One pound of ice, at one operation, is produced in 55 minutes; 6½ lb. may be made in one operation in 2 hours 40 minutes.

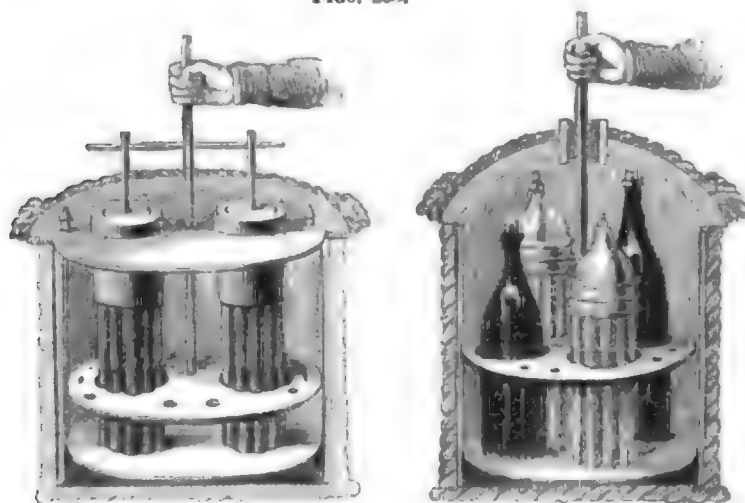
The manufacturing apparatus is designed for working on a large scale. One gallon of condensing water is required for the production of 1 lb. of ice. According to the size of the apparatus, 1 lb. of coal produces from 8 lb. to 15 lb. of ice. 11 gallons of liquid ammonia are required for the production of 26 lb. of ice per hour, and 126 gallons for the production of 440 lb. of ice per hour.

Ice-making or refrigerating machines, without actually making ice, are available for the cooling of hospitals and other buildings. It has been found that the interior of a chamber may be cooled down to within 6° of the freezing-point, whilst the thermometer outside stands at 90° Fahrenheit. For the cooling of wort in breweries and distilleries, and for facilitating the salting

and preserving of meat, the refrigerator is well adapted; also for the crystallization and reaction of various salts,—extracting sulphate of soda from sea water, crystallizing benzole, acetic acid, &c., extracting paraffin from oils, concentrating diluted solutions, &c.

Mr. G. Simpson, London, exhibited *Ash's piston freezing machine and wine cooler*, for freezing and moulding dessert ices, and icing wines. Chemical mixtures for producing cold without ice have long been known. One of the best is composed of sal-ammoniac and nitrate of potash, mixed in equal quantities; added to sulphate of soda, they make a powerful freezing mixture. The chemical action that takes place incurs the rapid absorption of latent heat from surrounding objects, hence the cold is produced. The action is greatly accelerated and intensified by the addition of water to the mixture, with agitation; and the substitution of the alternate action of the piston, to be moved up and down, for the rotatory motion, is the specialty in Ash's machine, which operates efficiently (figs. 258).

FIGS. 258.



ASH'S PISTON FREEZING MACHINE AND WINE-COOLER,
by Mr. G. Simpson, London.

CHAPTER VI.

AERATED-WATER APPARATUS.

Aërated waters or beverages, commonly so called, as soda-water, lemonade, and ginger-beer, are manufactured by the impregnation of the liquid with carbonic acid gas, in a close chamber, under great pressure, and with the aid of continuous agitation, the flavouring matter being in addition. It is in virtue of that gas that the effervescence of such drinks is produced when the cork is withdrawn and the pressure removed. The apparatus for the manufacture of aërated waters comprises, first, the generator, or the apparatus for producing the carbonic acid gas under high pressure; secondly, the means of impregnating the liquid with the gas; and lastly, the bottling apparatus.

Foreign manufacturers do not generally charge their aërated beverages under such great pressures

as are applied in England. In Germany, the consumers seldom care for more than two or three atmospheres of pressure in the preparation of their drinks.

Generators.—The English machines were exhibited without the generator and gas-holder; but, from the drawings, they appeared to be very much alike, having a strong leaden vessel for generating the gas, from whiting or chalk and vitriol,—that is, carbonate of lime and sulphuric acid. The leaden vessel containing the acid is swung on an air-tight joint, so as to drop the acid in small quantities on the whiting, as required. The sulphuric acid combines with the lime, forming sulphate of lime, and sets free the carbonic acid, which is collected in a copper rising-bell, in an oak tub, from which the condenser of the machine is supplied.

MM. Hermann-Lachapelle & Glover, Paris, exhibited a prettily-contrived apparatus, made of copper, with a glass vessel to hold the acid, and a vessel for passing the gas through water. This apparatus, though slightly enough in design, cannot be so lasting as the leaden generator, as it must be acted upon by the acid, and requires frequent renewal.

With reference to the washing of the gas by passing it through water, as it is delivered from the generator, some experienced makers assert that once washing is sufficient; others pass the gas successively through a number of vessels of water.

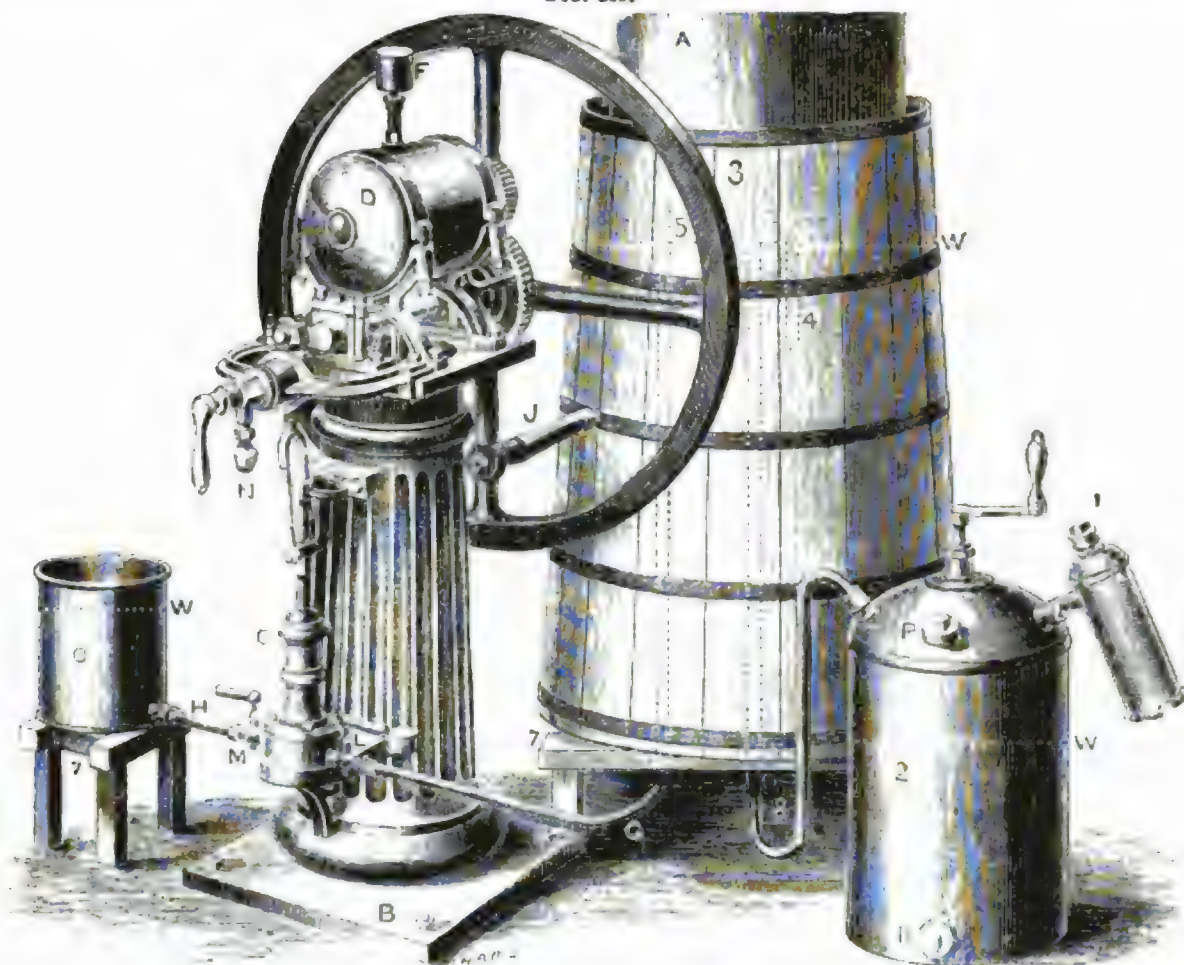
Impregnating Apparatus.—Messrs. J. Tylor & Sons, London, exhibited an impregnator, in which the condenser was made of sheet-copper, with a soldered joint; on this construction, access cannot be had to the inside, for tinning or for repair. The agitator has not any support outside the condenser, and the supply-cocks are without index-plates.

The pump is placed outside instead of inside the frame, in the way of the bottler. It is fitted with a bucket-plunger, worked from the top, in which the valves require to be kept up by a spring, which, if of steel, is subject to rust (fig. 259).

Messrs. Hayward Tyler & Co., London, exhibited two machines, in which there did not appear to be any means of ascertaining the various pressures to suit the various drinks, nor the level of the water in the condenser. The safety-valve is imperfectly designed. It consists of a plug $\frac{1}{2}$ or $\frac{5}{8}$ inch in diameter, fitted into, and capable of sliding in, a recess with a conical seat, terminating in an orifice $\frac{1}{4}$ inch in diameter, within which the pressure is received on the point of the plug. So soon as the plug is raised, the pressure acts upon its whole area, and it is consequently held up until nearly the whole of the gas is permitted to escape through a lateral orifice (figs. 260, 261, page 280).

Mr. B. Fleet, London, exhibited an inferiorly

FIG. 259.



SODA-WATER MACHINE, by Messrs. J. Tylor & Sons, London.

constructed machine in operation, manufacturing soda-water and lemonade. It has a cast-iron crank, and has no bottling-nose.

Mr. Samson Barnett, London, exhibited two machines of the best construction, and well designed, with massive framing. The globes or condensers are of gun-metal, turned and jointed with steel bolts and nuts, so as to be easily taken apart, either for cleansing or re-tinning. Large dial-gauges are attached, to show the exact pressures, distinctly marked, required for the different beverages manufactured. Gauge-glasses are also attached to show the quantity of water in the condenser. They were the best constructed machines exhibited for the purpose (figs. 262, 263, pages 281, 282).

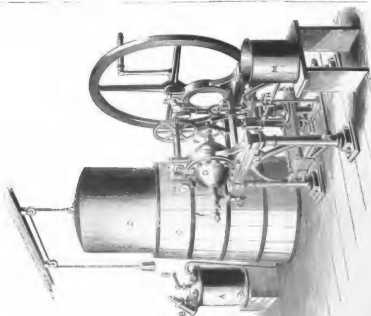
MM. Hermann-Lachapelle & Glover, Paris, exhibited an excellently-made machine, intended chiefly for supplying syphon-vases. The gun-metal condensers are well made; but the agitator has no external support. The pump is worked by means of the objectionable sling below, which, by its lateral straining, wears both the plunger and the packing. The framing is wanting in the solidity of the English frames.

MM. T. Gressler & Co., Berlin, exhibited a machine which presented a singular appearance, the condenser being placed on a separate stand. The speed of the agitator was not brought up by gearing.

Bottling Apparatus.—When alkaline drinks were more in use for medicinal purposes than for general consumption, there was little need for special bottling apparatus. Bottling by hand and knee fully answered all the requirements of the time; but when, about thirty years ago, the stamp-duty of three-halfpence per bottle was taken off, the consumption of aerated drinks was greatly increased, and the introduction of saccharine flavouring added still more to the demand. Thus, the carbonized water flavoured with citric acid, refined sugar, and essence of lemon, formed the sparkling lemonade; and this, with the addition of the extract of Jamaica ginger, formed the unfermented ginger-beer. Orangeade, nectar, imitation champagne, and other varieties, rapidly followed into the market.

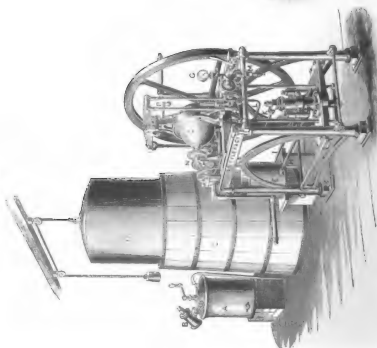
In the operation of hand-and-knee bottling, one end of the cork is fitted a little way into the bottle by means of a cork-squeezer, the bottler sitting in front of the bottling-nose of the machine, on a stool of such a height as to allow the knee-board to press the mouth of the bottle up against the leathered nipple by raising the heels off the ground. When the condenser is sufficiently charged, the bottler opens the lever or screw jam-cock (which is the only sort of cock that will remain tight under the rapid manipulation of aerated water under high pressure), and he partially fills the bottle. He

FIG. 203.

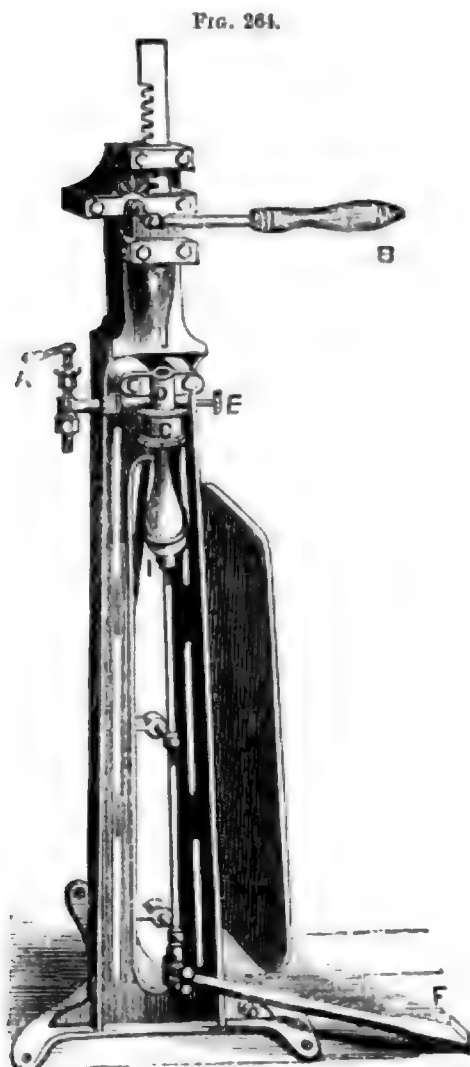


SODA WATER MACHINE, by Messrs. Hayward Tyler & Co.

FIG. 204.



SODA WATER MACHINE, by Messrs. Hayward Tyler & Co., London.



BOTTLING MACHINE, by Mr. Samson Barnett.

pense with the cork, by having a metal top on the bottle's mouth containing a valve, acted upon by a spring, and a spout outside to empty its contents into a tumbler. It has not been brought into general use, on account of the great expense and liability to get out of order, and the weakened condition of the water, which loses so much gas while being drawn off into the tumbler.

Motive Power.—Manual labour is found the most economical power where the demand does not exceed 2,500 bottles per day, as a man's services are otherwise available in a mineral-water manufactory when not engaged at the wheel. In many country towns a horse-wheel is advantageously employed, as the horse that carries out the goods is employed when at home for turning the machine. But where the demand is continuous, and above 2,500 bottles per day, steam-power may be applied with economy.

The usual way of driving with shafting and belts has often been attempted to be superseded by the application of a small steam-engine attached to each soda-water machine; but it does not appear to have been of any advantage, as those who adopted it have discontinued its use. Where the sale is large enough for power to be

employed, several machines are generally required, which may be worked by one length of shafting overhead, that will also pump water, wash bottles, &c.

Mr. Fleet exhibited a small steam-engine attached to his machine, by which it was worked. To regulate the speed, it had two fly-wheels and two cranks, and was connected by two cast-iron wheels,—the whole machine standing on ten legs.

Mr. Barnett exhibited a drawing of a steam soda-water machine, contained in one frame.

CHAPTER VII.

BREWING APPARATUS.

The principal feature of the brewing apparatus exhibited, consisted in the variety of refrigerators.

The importance of refrigerative power in brewing, more effectual than that of the ordinary wooden coolers, although generally acknowledged, is at the same time much underrated. Comparatively few breweries are furnished with a sufficient amount of cooling power, considering the effects of the exposure of wort to atmospheric influence. Though wort receives little or no harm from lying upon coolers for a short time, when the temperature of the air ranges near the freezing-point, yet in certain conditions of the atmosphere the injury done by such exposure is likely to result in spoiling the whole of the gyle. Before the introduction of artificial coolers, when brewers were entirely at the mercy of the old open coolers, they watched the weather with eagerness, and carefully avoided the days for brewing when the atmosphere felt close, and when drains and stagnant pools testified, through the sense of smell, that decomposition was going on much more rapidly than usual.

Nowadays brewers are rendered independent of weather by the adoption of refrigerators of sufficient power to cool the wort without exposure in open coolers. The requirements of an efficient refrigerator are, that it should possess a great extent of efficient cooling surface, not liable to be choked with hops, readily accessible, and easily cleaned; that it should not be disabled by deposits from water or by corrosion, which should be prevented; that it should be easily repaired on the spot by ordinary workmen, so as not to derange the operations of brewing; and, in general, that it should be economical in using the smallest possible quantity of water, that it should be adaptable to existing arrangements, and that it should work with but a slight head of wort.

Mr. J. Lawrence, London, exhibited a refrigerator consisting of 252 copper tubes $\frac{3}{8}$ inch in diameter, 8 feet 6 inches long, placed in rows of ten or more tubes, in a case of English oak,

capped at the ends with brass castings, to which the pipes are soldered in courses, fourteen or more in number, two or more rows forming a course or division. The oak case is likewise divided by removable wooden partitions into fourteen or more compartments, communicating with each other at alternate ends, therefore directing the course of the water backwards and forwards, and making it traverse a distance of 120 or more feet from its entrance to its exit. The wort passing through the pipes is directed by the removable caps or covers with which the ends are fitted, and which connect two courses together at each end alternately, thereby causing the wort to flow rapidly in an opposite direction to that of the water, and to traverse the same distance. The caps are readily removable for cleaning the tubes, and the joints are made with india-rubber packing. For cleaning the tubes, an elastic brush is used, consisting of india-rubber discs attached at the end of it, which cleans the tubes effectually. A leaky pipe may be at once discovered, plugged up, or replaced by a new one in a short time by an ordinary plumber. The refrigerator will work with the foulest and most corrosive of waters, as the tubes are easy of access on the outside, and may be freed from corrosive or other deposit by a brush being passed between them. The apparatus, it is stated, cools 22 barrels of wort per hour, under a few inches of head, down to 58° , with water at 52° , using $1\frac{1}{2}$ barrels of water to one barrel of wort.

Mr. Lawrence exhibited also a *mash-tun*, in which the old plan of propelling the stirrer by means of a rack at the circumference is replaced by a central propeller. Also, an improved *sparge* for sprinkling water over the goods. It consists of a pipe revolving on a central pivot, like a reaction-wheel, by the reaction of the water issuing under pressure from a series of small orifices along the pipe.

Mr. H. Bridle, Bridport, exhibited a *refrigerator*, in which a series of flat pipes placed vertically are arranged horizontally side by side in a case, about an inch apart. Each pipe is divided by a partition into two compartments, an upper and a lower, and is made of tinned copper. In the apparatus exhibited, which measures 6 feet by 3 feet, there are 47 pipes 7 inches deep, $\frac{1}{2}$ inch thick, and 3 feet in length, 1 inch apart. Each alternate pipe is jointed to the bottom of the case, so that the wort flows alternately over and under the pipes in one direction, whilst the water passes through the pipes in the opposite direction, traversing each pipe twice. With 22 barrels of water at 52° , 12 barrels of wort per hour are cooled down to 58° . With wort at 130° , 12 barrels of wort will be cooled by 12 barrels of water.

Mr. Pontifex exhibited a *refrigerator* of a novel construction, formed of copper discs placed one above another in a wooden vessel or vat. The apparatus is furnished with a balance-

weight and suitable tackle for raising the discs for the purpose of cleaning it, and for lowering it into its place, where it is secured and connected at the bottom by a union joint. The discs are connected together at their sides and their centres alternately, causing the wort to flow from and to the centres of each in its passage from top to bottom of the vat, the cold water passing at the same time inside the discs. They are constructed so as to fit the vat as nearly as possible, for which purpose the vat is made with a little taper. This manner of preventing the wort passing from one compartment to the other is imperfect, as the wort may pass at the edges. The actual amount of cooling surface is not more than about one-eighth part of that in other refrigerators.

Mr. R. Gibbon, Brentford, exhibited a *combined separating, dressing, and malt-crushing machine*, the object of which is to increase the quantity and quality of the extract by crushing the whole of the malt without breaking up the husk. The malt being crushed equally, the whole of the soluble matter of every grain is readily separated in the mash-tun, and the process of extracting is facilitated by the free drainage afforded by the mechanical support given to the mash by the husks being left as nearly entire as is practicable, which accelerates the drawing off of the worts. For these objects Mr. Gibbon divides the malt into three samples, viz., large, middle size, and small kernels, and employs three pairs of rollers, adjusting each pair of rollers to a sample. The malt is also freed from dust and other impurities in its descent to the rollers by the aid of a gentle blast of air. The object of this machine is excellent. Many brewers divide the malt into two or even three samples, but Mr. Gibbon appears to have been the first to combine the operations in one machine. The speeds of the rollers might probably with advantage be made independently adjustable, to suit the varying proportions of samples.

A malt balance is attached to the machine, designed to indicate the quantity of extract obtainable from each quarter of malt.

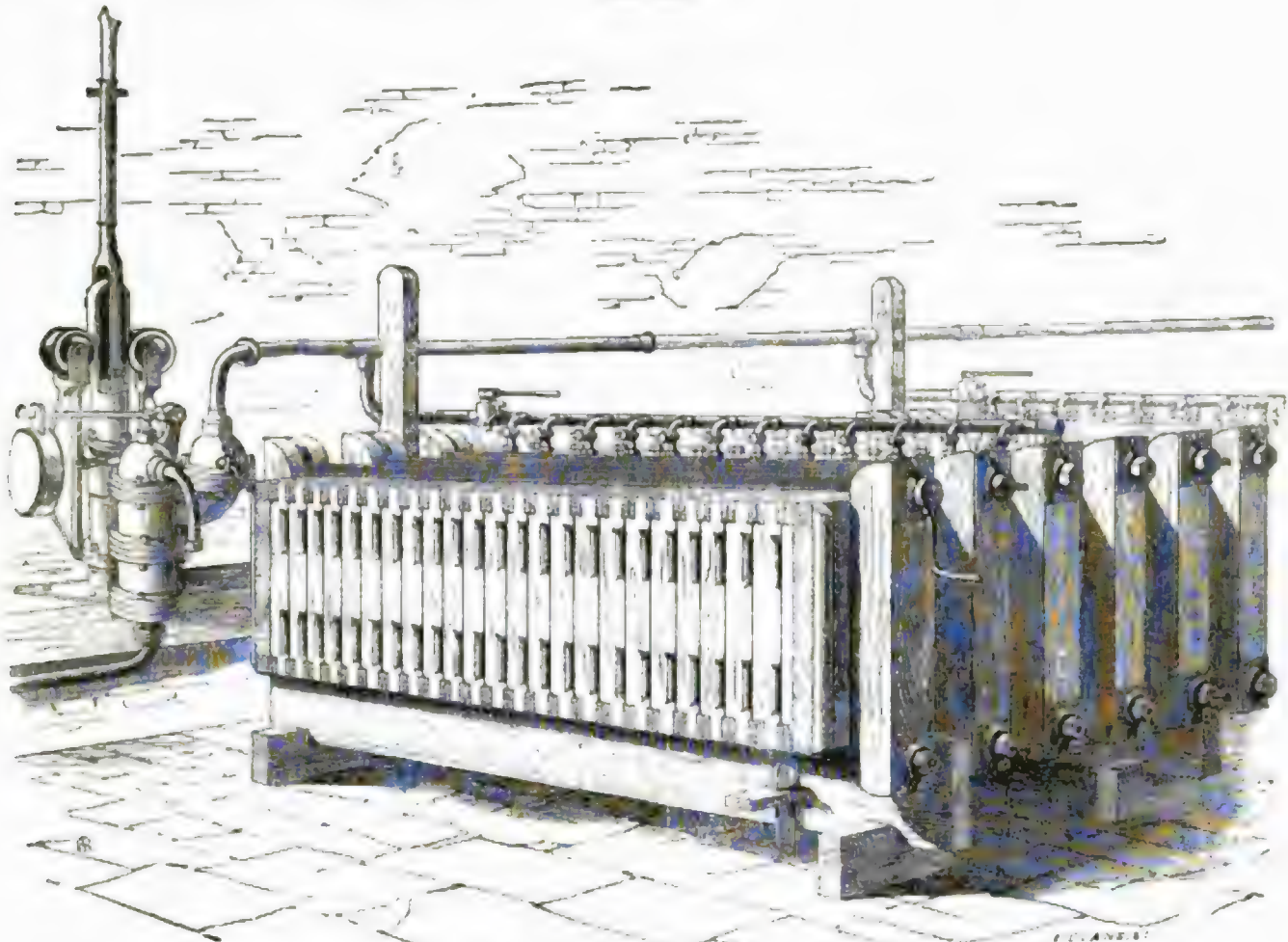
Messrs. A. Handyside & Co., Derby, exhibited Mr. P. R. Hodge's *hop-separator* and his *hop-press*, the latter being worked by hydraulic pressure. They are machines of good construction and workmanship. The separator divides the pollen and the seed from the leaf, and by breaking up the latter causes it to part with its extractive matter more freely. Mr. Hodge considers that the pollen, which is the most volatile and delicate portion of the hop, and contains the most delicate bitter, is nearly all lost in boiling by the old process. He argues that it is not necessary to put those volatile ingredients into the hot worts, as they are soluble at low temperatures, and may be added to the ales or porters during or after fermentation.

Messrs. Needham & Kite, London, exhibited a *filter-press* for semi-fluids, which is applied on

a large scale, not only by brewers for separating yeast from beer, but also by other manufacturers dealing with matters from which liquors are to be expressed. The yeast is pumped into linen bags placed between recessed wooden blocks ;

the beer is squeezed out, and runs away along the grooves provided for its escape, and the yeast remains behind in solid cakes. This machine has proved to be of great efficiency (fig. 265.)

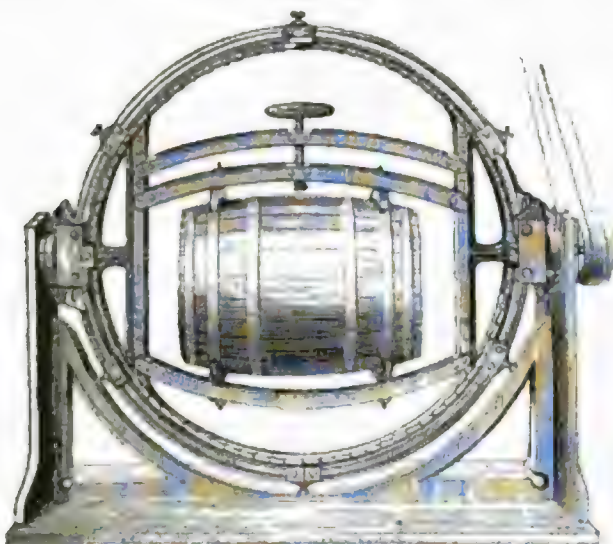
FIG. 265.



FILTER-PRESS FOR SEMI-FLUIDS, by Messrs. Needham & Kite, London.

Mr. Robinson, Bridgewater, exhibited a *cask-cleansing machine*, by means of which casks

FIG. 266.



CASK-CLEANSING MACHINE, by Mr. Robinson, Bridgewater.

may be cleansed without being unheaded,—a process which is frequently attended with injury to the cask. The cask is cleaned by means of

sharp grit, as flints broken small, and water. It is fixed into a skeleton frame, which is rotated by hand or by power. The novelty consists in an arrangement for gradually shifting the axis of rotation, so as to submit every portion of the interior surface of the cask to the action of the shingle,—across the staves, diagonally, and lengthwise. The change of position is effected by means of two excentrics working a pull, and turning the cask by one tooth of a ratchet-wheel at each revolution. The machine should be turned at the rate of from 25 to 30 revolutions per minute. For every 100 revolutions of the machine the cask makes one complete rotation within the frame. Cold water may be used ; but hot water is preferable, and is for foul casks indispensable (fig. 266).

There are, according to Mr. R. Davison, brewery engineer, 2,400 public breweries in the United Kingdom, in which about 20,000,000 barrels of beer are brewed annually ; and it may be assumed that at least an equal number of barrels annually require to be cleansed. Barrels used to be cleansed by means of steam, or hot water, or both, aided by a chain placed inside,

with a rolling motion by hand. In 1843, Mr. Davison, in concert with Mr. W. Lymington, introduced the first successful machine for the purpose, consisting of a double frame, suited to the form and size of each cask, the frames revolving one within the other, and at right angles to each other, in such a manner as to cause a chain of peculiar construction, assisted by hot water, to traverse completely every portion of the cask, and so effectually to remove all adhering matter. This machine is in high repute at many establishments, but its rate of performance is slow. Mr. Davison has recently, at the last

meeting of the British Association at Newcastle, described an improved machine which is capable of cleansing 100 dirty casks, or 60 mouldy ones, per hour. Old and tainted casks, he finds, may be cured by partial steaming, and subsequent exposure to currents of hot air at 450° Fahr. He considers that highly superheated steam is likely, for the most part, to supersede the existing processes; he tried its effect at a temperature of 600° or 700° upon a "very bad stinking cask," which, after ten minutes' exposure to the steam, was pronounced "perfectly sweet."

SECTION IX.

UNCLASSED MACHINES.

CHAPTER I.

MAGNETO-ELECTRIC MACHINES FOR PRODUCING LIGHT.

Professor F. H. Holmes, Northfleet, exhibited a *magneto-electric machine for producing light*, and a *light regulator*, in action in the Western Annex. This machine was designed, and is specially applicable for lighthouses. It has been said that it was absolutely impossible to produce light from a magneto-electric machine: such a light was first produced by Professor Holmes, and was exhibited by him in 1855, when M. Becquerel took occasion to remark that none but a fool or an Englishman would have believed it possible. In 1831, it was discovered by Faraday, "that when a piece of soft iron, surrounded by a metallic wire, was passed by the poles of a magnet, an electric current was produced in the wire, which could be exalted so as to give a spark." And since that time, to the knowledge that, whenever the magnetic force in a piece of soft iron or steel is being increased or diminished, a current of electricity will be induced in a coil of insulated wire wound round such piece of soft iron or steel—has been added these laws: First, that the force of the electric current thus induced is proportional to the magnitude of the increase or diminution, divided by the time in which the change takes place; and, secondly, that the current thus produced is modified by the length and diameter of the wire in the coils. Upon these principles the machines have been made, which gave the lights at the South Foreland, and at Dungeness, and in the Western Annex.

"Light," says Professor Holmes, "may be produced by mechanical means, by chemical action, and by electricity. Experiment proves that mechanical means, unassisted by chemical

action, can produce light of any intensity, nearly equal to a good gas-light; but at that point the production of light, by that means, stops. Chemical action can go further, and produce lights of various colours and intensities; and many mechanical contrivances have been applied to a light obtained by this means, either to produce a given amount of it with the least cost of material, as in the argand burner; or, by mixing the materials employed, so as to cause the chemical action to be as violent as possible, to produce a more intense light, as in the blue-light, or the lime-light.

"The intensity of the light produced by chemical action depends on two conditions, viz:—that there must be solid particles in a condition capable of taking up the velocity, and chemical action to impart the velocity to them. For instance, in the lime-light we have the combination of hydrogen and oxygen, which produces of itself but very little useful light, as it is purple; but when the flame impinges on a piece of lime, the heat produced by the combining gases sublimates the lime, and then the particles, or atoms, floating in the flame—though they are not of themselves concerned in the chemical action going on—produce an intense white light. In the oil lamp, the hydrogen of the oil unites first with the oxygen of the air; and, during this combination, the particles of liberated carbon are floating in the combining gases, as were the particles of lime before; but as the combination in this case is not nearly so violent, or, in other words, as the velocity of the combining hydrogen and oxygen is not so great, the light produced is less intense. The intensity of the light depends on the number of particles or solid atoms put in motion, and the velocity with which they move; and if the velocity of chemical action could be increased beyond that of the combination of hydrogen and oxygen, and by these means the

velocity of the solid particles increased, the intensity of the light would also be increased; and it follows that if there be any means, transcending chemical means, by which solid particles of matter can be put in motion with a greater velocity, and in greater quantity and number, that means will produce a more intense light. Such a power will be found in electricity.

"Before passing to its consideration, it may be well to note another reason why the lime-light is very intense to the eye, as compared to the oil-lamp. That is, because the whole thickness of the flame produces light, and therefore the eye is affected by the whole of the vibrations taking place in a diameter of the flame in the direction of the ray. In an oil-lamp which has four concentric wicks, eight thicknesses of flame appear to give off rays; and the sum of these eight thicknesses of flame, if they were solid, would be greater than the diameter of the lime-light; but the lamp flames are hollow, and it is only on the surfaces of each flame that the chemical action is taking place, to the depth, probably, of $\frac{1}{160000}$ part of an inch. If, then, all the sixteen thicknesses—that is to say, the two surfaces of each of the eight shells of light—be added together, the sum will fall far short of the diameter of the flame in the lime-light.

"For the foregoing reasons the lime-light is the most intense continuous white light produced by chemical action. Intensity can be increased by increasing the velocity of the combining atoms; but this would convert combustion into explosion. An explosive mixture can be made that shall, on ignition, produce a light even more intense; but as it only lasts an instant, it does not come under the head of that which is generally understood as a source of light.

"In passing to the third source of light—electricity—it will not be necessary to compare it with the oil-lamp, which is inferior to the lime-light, but only with the latter and with explosives. Most people must have observed the difference between the illuminating power of a flash of gunpowder, even from a large gun, at night, and the vivid glare thrown on surrounding objects by a flash of lightning; although the duration of the lightning-flash is but a thousandth part of the time occupied by the flash of the powder. If, instead of regarding surrounding objects, the eye be directed to the flashes themselves, the difference is still more extraordinary; for a flash from a large gun is altogether invisible, if the gun is fired immediately after the lightning, at a certain distance from the observer, and in the direction of the lightning: in fact, experience teaches that nothing but the sun equals the lightning's flash for intensity; and often during a thunder-storm at night, the light of the flash may be observed to penetrate and illumine clouds that no other light but the sun could illumine.

"On comparing this light with the direct rays

of the sun, no difference could be found, either in intensity or colour. The prismatic analysis, according to Dr. Gladstone (who tried the experiment), is in favour of the magneto-electric light; the intensity being as 7 to 6. This, too, was with the light at half its usual power, and at 24 feet distance from its analysing prism.

"The conclusion, therefore, is, that the magneto-electric light is the most intense light that can be produced, far exceeding any light generated by mechanical means, or by chemical action, equal in intensity and penetrating power to lightning, and apparently of the same nature as sunlight."

The machine is capable of being easily maintained in continuous action, as has been proved at South Foreland and Dungeness during the long nights of three winters. It was exhibited in regular action every day in the Western Annex, from half-past one till five o'clock.

The apparatus for a lighthouse necessary for the production of this light, consists essentially of two pieces: one for the production of the electricity, which is the magneto-electric machine; and the other, a contrivance by which the current of electricity so produced is made to regulate its own flow, and give out the greatest light possible without interruption. This is the regulator or lamp.

In the arrangement of the magneto-electric machine, the objects have been: first, to arrive at a maximum of electricity from a given weight of magnets; secondly, to modify the current by the length of wire in the coils, so that the "shock" shall be trifling, but the intensity shall be still great enough for its purpose; and, thirdly, to produce a permanent light. Above all things, therefore, the machine has to be constructed in such a manner that no visible cause of getting out of repair shall exist.

The machine consists of three circles of horse-shoe magnets, 17 inches long, made of bars 2 inches by $\frac{1}{4}$ inch in section, fixed in a cast rim. There are twenty-two magnets in each circle, or sixty-six magnets in all, weighing one ton; the magnets in the two outer rings consist of four plates, and in the inner ring, six plates. The poles of the magnets are $2\frac{1}{4}$ inches apart, and form a circle 5 feet in diameter. They are permanent magnets of cast steel, which should be tough, not brittle:—of a fine grain, yet slightly fibrous. They are operated by means of two series or circles of soft-iron cores, eighty-eight in all, and weighing 85lb. The circles alternate with, and revolve between the magnets; and they are of the same pitch as the magnetic poles, namely $4\frac{1}{4}$ inches, so that the cores in each revolving ring are simultaneously covered by the poles of the magnets, and simultaneously exposed alternately. The cores are carried in a brass wheel-casting, with which they revolve so as just safely to clear the poles of the magnets:—the more slowly they can be set without touching, the more electricity is excited. The best

maximum speed of revolution is from 110 to 120 revolutions per minute. The cores are covered with helices of copper wire (No. 9 wire-gauge), containing 40 feet of double wire, or 80 feet of single wire, on each core. The wires in the helices are consecutively connected, two inner ends and two outer ends alternately, forming uninterrupted conductors round the two circles, of which the two pairs of free ends are carried from the coils through the axle to the front, whence they are led and separately screwed to the commutators, one to each pair of wires.

The magnets in each circle are arranged with their north and south poles regularly alternating; these poles alternate also with those of the opposite magnets in the neighbouring circles. Further, the cores are so arranged that whilst the cores of one circle coincide with, or are underneath, the poles of the two circles of magnets between which they revolve, the cores of the other circle are intermediate between the magnetic poles. In the course of one revolution, then, each core is subject to forty-four changes of magnetism, or reversal of its poles; and at the rate of 110 revolutions per minute, the changes would take place 4,840 times in a minute for each ring of cores, or nearly 10,000 times per minute, for the two rings of cores alternately.

The quantity of electricity induced in the wires of the helices being proportional, amongst other conditions, to the amount of magnetism induced in the cores, two points should be specially attended to, in order that this amount should be a maximum: first, that the steel magnets should be strong, and, for lighthouses, should retain their original strength. To arrive at the proper proportions, much and expensive experiment has been undertaken. Mr. Holmes discovered that the armature may be too heavy, and weaken the magnet to such an extent as to require to be re-magnetized. He found that the armature should have exactly one-forty-eighth of the weight of the magnets,—say one-fiftieth; and his machines, contrary to ordinary experience, remain stronger at the end of six months than at first. The second point is, that, in their revolution, the ends of the cores should pass as closely as possible to the poles of the magnets without touching them, as contact with the poles would endanger the integrity of the machines. Hence, no wood or similar substance can with safety be employed to retain the magnets in their place; for a change of humidity would disarrange all; in fact, the total destruction of a large machine at Brussels was caused by the use of wood for this purpose. The magnets, therefore, in the Northfleet machines, are mounted entirely in brass, and are retained in their exact position by strong set-screws, so that any disarrangement is an impossibility.

The commutators are simple contrivances, for the purpose of giving a steadier, whiter, and more intense light; the alternating currents of electricity induced in the helices being directed

so that not only does the entire current pass from the machine in one direction, instead of alternating, but the dead points in the current are counteracted, so that the current, instead of being intermittent, is constant. Each commutator consists of two brass discs with square teeth, which interlock with each other, or mutually occupy the interspaces, as in an ordinary shaft-coupling with fast-and-loose clutches. The teeth do not touch each other at any point, but are placed $\frac{1}{16}$ inch clear, for insulation, as it is a characteristic of current electricity that it will not, like frictional or static electricity, dart through space. The teeth are the same in number as the magnets, and the electricity is collected from them by two rollers, which run over, and are maintained in rolling contact with them, by springs, and which break contact at every interspace, in passing from a tooth of one disc to a tooth of the other. Thus, whilst in each commutator, one roller collects and transmits all the positive currents, the other roller collects and transmits all the negative currents.

The electricity, by means of the conducting wires, arrives in the lantern, where it is produced between two "carbons," or sticks of graphite,—obtained from the insides of gas retorts,—a compound of carbon, iron, antimony, silicon, and other matters. The carbons are 6 millimetres, or about $\frac{1}{4}$ inch, square, arranged vertically, one over the other; and as the upper or positive pole is maintained at a white heat, whilst the lower or negative pole is scarcely reddened at all, it is found that the upper one is consumed twice as fast as the under one. They are, accordingly, prepared respectively 12 inches and 6 inches in length, so as to equalize their duration. In order to maintain the light in true focus, the rate of feed for the upper carbon is twice that for the under one. The consumption of carbons was at the rate of 3 inches per hour in the Western Annex,—2 inches of positive and 1 inch of negative carbon; but in lighthouses with two machines, it amounts to $5\frac{1}{2}$ inches per hour.

The light-regulator is a piece of clock-work, governed by electro-magnets, automatic, to feed the carbons, and to regulate their distance apart, so as to maintain the light at a constant degree of intensity. The strength of the current is adjusted by means of a galvanometer. The distance between the carbon points does not vary more than $\frac{1}{32}$ inch.

The revolving-wheel is turned by a direct-acting steam-engine, of one cylinder $5\frac{1}{4}$ inches in diameter, 12 inches stroke, with 20 lb. steam, consuming 17 lb. of coke per hour.

MM. A. Berlioz & Co., Paris, exhibited a *magneto-electric machine* for the production of light, on Professor Holmes' system, with the exception of the commutators, which are omitted. The terminal poles of the coils are connected with one of M. Serrin's electric lamps, which gives a light of considerable brilliancy, notwith-

standing the employment of currents in alternately opposite directions. The light is, nevertheless, not white, like Mr. Holmes's, nor is it so steady. It is surrounded by a column of rose-coloured light, the rose-tint being due to the presence of carbonic oxide, the result of the imperfect combustion of the carbons, which is the effect of the alternating currents; and the comparative unsteadiness of the light is to be traced to the same cause. Photographs of the two lights, with and without the commutator, are very different. The machine contains forty magnets and sixty-four cones, and makes from 300 to 400 revolutions per minute. The light generated by this machine is said by the exhibitor to be equal to that of 125 carcel lamp-burners, each burner consuming 40 grammes (about 26 oz.) of oil per hour; and the power required to work the machine is said to be $1\frac{1}{2}$ -horse power.

CHAPTER II.

TELEGRAPH-CABLE MACHINES.

Messrs. Siemens, Halske, & Co., London, exhibited a *telegraph-wire-covering machine*, the invention of Mr. C. W. Siemens. The conductor, or insulated wire, is insulated by india-rubber and an exterior coating of gutta-percha, with a flexible casing of copper or brass. The conductor, being either a solid copper wire or a strand of several wires, as occasion may require, is first coated with a thin film of an insulating compound, known as "Chatterton's Compound." The wire thus prepared is then covered with pure india-rubber, by a peculiar process, in which the application of heat is avoided. The india-rubber bands are laid longitudinally on the wire, and joined in the covering machine by bringing fresh-cut edges together under great rolling pressure. Where several coats of india-rubber are applied, the longitudinal seams of successive layers are made to occur at right angles to each other. The insulated wire is next covered with "Chatterton's Compound" and gutta-percha, to give protection to the more tender india-rubber. The advantages claimed for this method consist, chiefly, in rendering the occurrence of faults almost impossible, and in obtaining, in the combined india-rubber and gutta-percha covering, the high insulation and low induction due to the former. The manner in which the india-rubber strips are laid on produces an absolute concentric coating, free of all flaws or air-holes. The centricity of the conductor in its insulating medium is not risked by heat, to which the cable may be accidentally exposed, as india-rubber retains its solidity at temperatures at which gutta-percha readily softens and allows

the conductor to sink through, which frequently takes place. The thin coats of insulating compound interposed between the copper and rubber, and between rubber and gutta-percha, secure firm adhesion among these materials. In handling the wire, the gutta-percha serves as protector, and also reduces the electric charge.

To form the wire just described into a cable, it is covered with a double layer of hemp strings of the strongest material, saturated in Stockholm tar, laid on spirally, and under considerable tension, the twists of the two layers running in opposite directions. It is then finally covered by a flexible copper or brass sheathing, composed of bands of sheet copper or brass, put on spirally under the influence of great pressure, and with each succeeding turn overlapping the preceding. The covering thus produced resembles the scales of a fish, affording protection without being wanting in pliability. The phosphuretted copper or brass applied for the purpose does not corrode in sea-water, but remains in perfect condition for a great number of years. The tensile strength and low specific gravity of the cable, and the impossibility of the metal sheathing uncoiling or kinking, will, it is said, remove all difficulties and risks connected with the laying of iron-covered cables of the description heretofore adopted, and will also be the means of enabling the cable to be lifted in very great depths, after the expiration of many years.

These cables are designed chiefly for submarine and underground lines, and for many overground purposes. In the machine for manufacturing the cable, the strips of india-rubber are drawn by rolling pressure tight upon the wire, so as thoroughly to exclude air; they are cut at the proper inclination, and the edges joined nearly at the same instant at which they are cut. The machine consists chiefly of two grooved pressing rollers and two circular shears. The shears are so placed, one on each side of the grooved rollers, that, in turning, their cutting edges cross the circumferences of the rollers a little before the centre line, at a point where the distance between the two circumferences is equal to half the thickness of the strip. The wire or strand to be covered, and the two strips of india-rubber, are guided through the machine, which, pressing on the wire, and catching the strips between the cylindrical portions of the rollers, shears off the superfluous portions, and immediately pushes the fresh-cut edges into the groove by heavy rolling pressure. Several coatings in succession are applied in this way, breaking joint, through rollers with successively enlarged grooves, the wire passing straight through the series. The seams are found in practice to be as sound and strong as the body of the material. Mr. C. W. Siemens, in describing the machine,* submits a table of the specific non-

* See "Proceedings of the Institution of Mechanical Engineers," 1860.

conducting and inductive powers of different substances, from which it appears that at 52° Fahrenheit, the specific non-conducting power of india-rubber is seventeen times as much as that of gutta-percha; and that, at 92°, it is seventy-three times as much,—showing the superior fitness of india-rubber to gutta-percha, in respect of insulating power.

Mr. A. Smith, London, exhibited models of his *machinery for making submarine cables and wire ropes*, as used in the manufacture of the late Atlantic cable. The bobbin-frames and bobbins are placed one behind another, all in the axis of the revolving frame, and remain stationary in that position, while the frame alone is made to revolve. By this machine an increased speed is attained, as compared with the older machines, in which the bobbins are mounted on one or more revolving tables, and the bobbins, with their frames, containing sometimes half a ton each, are carried round the common centre, and caused to rotate on their own centres once for every lay. This is an important advantage, because, in course of working, some of the bobbins are full, while others are nearly empty; and, in the case of the old machinery, a great strain is thereby thrown on the parts of the machine from the variation of the weight. Mr. Smith's machine is capable of making 10,000 yards of strand per day of ten hours, instead of only 2,500 yards, the usual amount by the ordinary form of machine.

CHAPTER III.

PEAT MACHINERY.

Mr. J. D. Brunton, London, exhibited *machinery for straining and moulding peat*, on Buckland's patent. The deposits of peat in Great Britain and Ireland occupy an area of not less than 6,000,000 acres. In Ireland, these deposits are commonly called bogs; in Scotland, mosses; and in England moors and heaths. But they are all of similar character, being composed chiefly of vegetable matter, wholly or partially decomposed, and retaining a large quantity of water. The peat near the surface is generally of a light colour, and spongy or stringy; it becomes browner and more dense at a greater depth, and quite black towards the bottom of the deposit, where it is sometimes hard and solid. The thickness of the peat in different localities varies from 2 feet to 40 or 50 feet. Assuming the average thickness to be only 12 feet, an acre would yield about 3,500 tons of dried peat; consequently the aggregate estimated acreage in this country would produce 21,000,000,000 tons of dried peat,—equal to the supply of 21,000,000 tons per annum for a thousand years.

Peat, when dug from the bog, generally contains from 50 to 75 per cent. of water. The difficulty of getting rid of so much moisture has caused a preference to be given to the uppermost portion of the deposit, which abounds most with roots and coarse fibres, and parts most readily with the water not actually shut up within those fibres. In this condition it produces an inferior fuel, which will not withstand a blast, and makes an imperfect charcoal. The abundance of peat and the paucity of other fuel in Ireland, together with the poverty and distress in that country in 1846, led to the origination of a benevolent scheme for employing the destitute population in the preparation of peat for home consumption, and of peat charcoal for exportation to the great iron-works in England and Scotland. A large capital was raised, and liberal profits were anticipated, but never realized. Though wages were very low, the time and labour occupied in cutting the turf and drying it entailed a cost which left no margin for profit. It was found that the air-dried peat, at the end of several months after the turf was cut, contained from 25 to 30 per cent. of moisture, the dispelling of which left a comparatively small part of the bulk for serviceable ignition. This led to the invention of ingenious machines for expelling the water from the peat by centrifugal force, and of consolidating the peat so dried by hydraulic pressure. A superior article was thus produced; but the cost of the machinery, and the power requisite to work it, prevented the manufacture from being remunerative. Ingenuity and skill were also exercised in extracting valuable products from peat; viz., naphtha, paraffin, volatile oil, acetate and carbonate of ammonia, &c. The paraffin was converted into candles superior to those made of wax; but here again the apparatus and the processes were too costly to be profitable.

To produce a perfect article, the coarse roots must be removed, and the smaller fibres must be broken up; and it is the object of Mr. Brunton's machine to do so economically. Immediately the peat is dug from the bog, it is thrown or tipped into a hopper, beneath which is a strainer formed of perforated metal, and within the strainer is an archimedean screw. At the bottom of the strainer is a small opening, through which any very coarse, undecomposed roots and fibres, which will not pass through the perforations of the strainer, fall into a waste pipe and are rejected, or may be used for any purpose not requiring superior fuel. By turning the screw within the strainer, the small fibres are cut up by the sharp edges of the perforated metal, through which they pass with the decomposed part of the peat, and with which they thus become assimilated. A strainer of two feet in diameter, with perforations of one-eighth of an inch diameter, and fifteen to the square inch, contains about 12,000 holes, which are equal to an aggregate aperture of a square foot; a strainer

of this size will discharge about 8 tons of peat per hour, or nearly 100 tons in twelve hours. The decomposed peat protrudes through every hole in the strainer, and drops in vermicular forms upon an endless band, which delivers the strained peat into one of Clayton & Co.'s small brick-making machines, by which it is moulded into any suitable shape or size that may be preferred. The strainer being enclosed in a heated chamber, with an opening for the escape of steam, the moisture is rapidly driven off from the worm-like strings as they fall upon the band, giving solidity to the moulded blocks of peat as they pass through the die of the brick machine. By their being then at a high temperature the subsequent process of drying is expedited. The moulded blocks of peat are removed to a drying-shed, through which a current of hot moist air passes; and they soon, without compression, become as hard as oak, and more dense than any peat submitted to hydraulic pressure. From four to five tons of wet peat, as taken from the bog, are required to make one ton of dry condensed peat, the total cost of which is said to be about 3s. 6d. per ton. Peat thus prepared is said to burn very freely, to stand a blast, to emit considerable heat, to be smokeless, and to produce less ash than the average of coal or of coke. It is impervious to water, improves by keeping, and is incapable of self ignition. From two-and-a-half to three tons of prepared peat will make one ton of excellent charcoal; and in converting the peat into charcoal, one cwt. of peat tar may be drawn from one ton of peat.

From an analysis of some samples of peat prepared by Mr. Brunton's process, by Mr. W. T. Rickard, it appears there was but a trace of sulphur to be found in them, and no phosphorus at all. The following is the analysis:—

Moisture	2·00
Hydrocarbons	67·00
Coke	30·97
Sulphur	0·03
	100·00

Of ash there was 2 per cent., consisting of lime, alumina, silica, and peroxide of iron.

The specific gravity of ordinary peat seldom surpasses ·800; that of peat subjected to hydraulic pressure is 1·08; whilst that of the condensed peat prepared by Mr. Brunton's process has been found by Mr. Versmann to vary from 1·15 to 1·50, and to average 1·30.

CHAPTER IV.

DIAMOND-CUTTING MACHINERY.

Messrs. Hunt & Roskell, London, exhibited in operation a *machine for cutting and polishing diamonds*, attended by Mr. L. M. Auerhaan.

The chief difficulty in cutting diamonds lies in the fact that diamonds are the hardest known substance. Diamonds can only be cut by diamonds. The first step taken with diamonds of ordinary size is to set them in a cement composed of three parts of lead to one part of tin, on the ends of two pieces of wood, and rub them together, when the one diamond grinds the other away to something near the form required. The dust, which is of considerable commercial value, is preserved for the purpose of polishing the diamonds. For polishing, the diamond is embedded in soft metal, and by means of clamps it is brought to bear upon the skieve at the proper angle. The skieve is a flat circular plate of soft Swedish iron, 14 inches in diameter, revolving on a spindle running in lignum-vitæ bearings, and making 2,400 revolutions per minute, a speed which is adapted for all sorts of diamonds. Too much speed sinks the diamond in the powder. The skieve is made perfectly flat. There is no means of knowing beforehand how the iron is to turn out: what suits one workman may not suit another. If the iron is too soft, the diamonds never acquire a brilliant surface. Soft iron removes the soft parts of the diamond; hard iron is best for removing the hard portions of diamonds. The soft parts of the diamond are ground first, to leave dust in the skieve for the harder portions.

Thus, the cutting and the polishing of diamonds are two distinct operations. The cutting is a merely preliminary process, to prepare and assist for the polishing, and, as may be supposed, it is always endeavoured so to treat the diamond as to reduce it in size as little as possible. The diamond dust is mixed with sweet oil, for polishing; and every particle of dust is found under the microscope to be a perfect tetrahedron, or four-sided solid, having triangular faces. It is necessary, in polishing, to follow the grain of the stone, otherwise the stone is not acted upon, but itself scratches the iron. The same necessity does not exist with the oriental stones, as rubies, emeralds, and sapphires, the working in which belongs to another trade, for which brass skieves are used.

"Carbon of diamond," a black, opaque substance, is found in the mines with the diamonds, and is the best substitute for diamond powder for polishing them. One workman can cut and polish eight small diamonds per day of ten hours; of those there are eight to the carat, 2,400 carats being equal to 1 lb. troy. Previously to the introduction of cutting, one workman could polish only three such diamonds in a day. Old stones, polished without cutting, do not possess the same degree of lustre as the more modern ones; as the cutting process yields diamond powder, which is finer than the "diamond boards," previously in use, and therefore gives a superior polish. The older stones, also, were not polished quite flat,—another reason for their dulness. In India, the natives chiefly

care for size, less for brilliancy. The reduction of material in cutting and polishing diamonds from the rough state averages 40 or 42 per cent. of the whole weight; and the dealers are well satisfied if they get 60 per cent. of the weight in the finished stone. Each of the stones in the eardrops of the Empress of the French required four months to cut and polish from the rough state. They each weigh twenty-five carats. The Koh-i-noor was originally polished on the old system,—hence the dullness of that celebrated stone before it was repolished; it was exhibited in 1862, and its brilliancy was remarkable.

Rough diamonds are brought from mines at Rio Janeiro, Bahia, Calcutta, Madras, and Golconda; chiefly from Rio Janeiro and Bahia. The Bahian diamonds are the most recent and the best. The other mines are nearly exhausted.

In Holland, the head-quarters of the diamond trade, there are three branches of trade,—the cutting, the polishing, and the splitting. An expert in one branch cannot work in another. But the Dutch diamonds are not endurable in England, as the wages are screwed down, and the work is not perfect.

CHAPTER V.

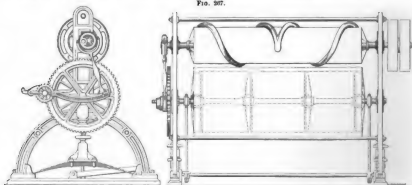
MACHINES FOR WORKING IN LEATHER.

Messrs. Stothert & Pitt, Bath, exhibited two machines for working in leather: *one for striking and scraping leather hides*, the other for rolling

leather. By the first machine, on Pitt & Cox's patent, the mechanical processes of rubbing and scraping hides are performed. They comprise the operations of depiling, scudding, striking, smoothing, slicking, and stretching, which are usually done by hand. The hide is carried over a cylinder, on which it is presented by a gradual progressive motion to the action of a revolving spiral knife, in the form of a right-and-left-handed screw, fixed on a revolving cylinder just over the other cylinder. The hide-roller is pressed towards the spiral roller by a spring; and as the spiral touches at only two points at a time, traversing the hide from end to end as it revolves, every portion of the hide, though of varying thickness, is ingeniously brought under the direct action of the knife. The hide is fed or progressed under the knife by means of a ratchet motion (fig. 267).

The second machine, on Ripley's patent, for rolling and finishing leather, is intended to supersede the ordinary manual process of operating with a loaded box mounted on rollers, which is urged backwards and forwards over the surface of the leather by hand. This reciprocating motion is effected by means of a steam cylinder, of which the piston-rod is directly connected to the loaded box (fig. 268).

Mr. W. D. Richards, Boston, U.S., exhibited four machines for working in leather,—one for *leather-splitting*, to reduce sole-leather to any required thickness, and for making soles uniformly thick; another for *sole-cutting*, by which twenty pairs of soles may be cut per minute, into any form, by means of solid dies fitted to the last, and dispensing with the use of the



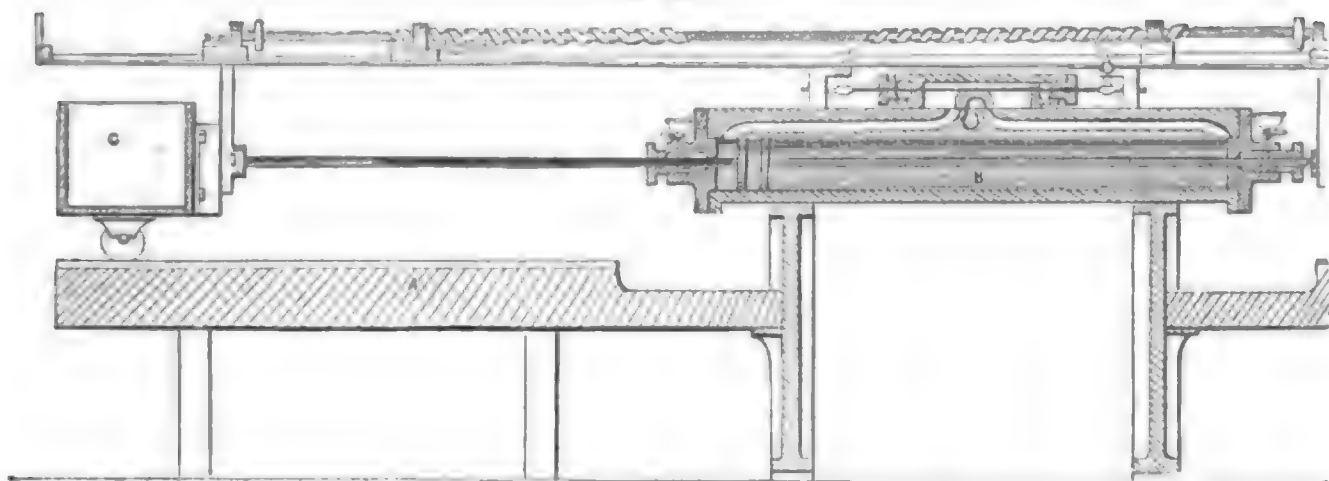
MACHINE FOR STRIKING AND SCRAPING LEATHER HIDES, by Messrs Stothert & Pitt, Bath.

hand-knife in fitting; another for *cutting soles of any width* required, with one pair of knives, at the rate of sixty soles per minute; and the fourth for *heel-trimming*, capable of trimming in a minute one pair of heels on the shoe, of any size and shape.

MM. Chouillon & Jaeger, Paris, exhibited a *grindstone for thinning leather*, against which the leather to be made thin is pressed by hand, so dispensing with the thinning-knife.

M. Lemercier, France, exhibited a *shoe-pegging machine*, in which small screw-pegs are used

FIG. 268.



MACHINE FOR ROLLING LEATHER, by Messrs. Stothert & Pitt.

instead of plain pegs. The screw is cut on a piece of wire, which is then screwed into the sole, and cut off at the surface.

Mr. C. Topham, London, exhibited an *elastic rotary cleaner and polisher* for boots and shoes, in which a pair of elastic rotary brushes, for scouring and for polishing, are turned by means of a treadle.

Mr. J. Rawlings, London, exhibited a *boot and shoe cleaning machine*, a simple construc-

tion of boot-tree, which is readily contracted to receive a boot or a shoe, and then expanded to hold it firmly while being blacked or polished. It is intended to be fixed to a wall or post, so enabling the cleaner to work with both hands, and expedite the operation. The boot being properly filled out upon the tree, receives a better polish more easily, and the inside is kept cleaner than by the usual mode of cleaning, in which the hand is thrust into the boot. There are two forms of this machine: one for adult sizes with a fixed foot, the other with a fastening by means of a slot and swivel pin, by which various sizes of blocks may be fastened to the body of the tree to receive different sizes of boots or shoes for being cleaned, as well as for being treed (fig. 269).

FIG. 269.



BOOT AND SHOE CLEANING MACHINE, with fixed foot, by Mr. J. Rawlings, London.

CHAPTER VI.

MACHINES FOR WORKING IN TOBACCO, AND FOR PIPES.

M. Voigtländer, Schladen, Hanover, exhibited a *tobacco-spinning machine*. A horizontal flyer receives the tobacco to be spun, from the table, through one of its bearings, which is hollow, to the bobbin, which is suspended between the wings of the flyer at right angles to the axis of the flyer. The bobbin is turned on its axis, and takes up the spun tobacco, which is guided to the roller by means of an alternate traversing motion obtained from a double-cut screw, right and left handed. The degree of twist, the speeds, and the size of rope are changed by changing the pulleys on the flyer shaft. The tobacco to be spun is fed by hand.

M. Julius de Bary, Offenbach, exhibited a *cigar-making machine*. Cigars are compounded from three kinds of tobacco, known as "filler," "bunch-wrapper," and "wrapper." In making cigars by hand, the requisite quantity of filler is formed into a "bunch" by enclosing it in the bunch wrapper. The bunch is then covered

with the wrapper laid on spirally. The object of the machine is to make the bunches, which are afterwards covered and finished by hand. The filler tobacco is conducted by an endless band on pressure rollers to a knife which acts vertically, and at each revolution cuts off the proper measure of filler tobacco. From the other end of the machine, the bunch wrappers are fed in on an india-rubber band. By a suitable mechanical adjustment, of considerable nicety, each measure of filler tobacco is caught by an india-rubber band stretched on a segment of a circle, and simultaneously the bunch wrapper arrives and is rolled over the filler tobacco upon the circular segment by a reciprocating motion imparted to the segment. The rolling being completed, the bunches are delivered upon an endless chain, from which they are removed by an attendant. To facilitate the operation, by stiffening the bunches, they are wrapped in paper by the machine, the paper being removed before covering the bunch.

By the use of this machine, a saving is said to be made of two-thirds in wages for attendance; and there is a saving in tobacco also. The defects of cigars made by means of previous bunch-making machines, consisted in the irregular draught and combustion through the cigars, owing to their unequal consistence. The new machine produces from 12,000 to 15,000 good bunches per day.

Mr. J. G. Reynolds, London, exhibited apparatus for *manufacturing tobacco-pipes*. The manufacture of tobacco-pipes is said by Mr. Reynolds to consume nearly 40,000 tons of clay per annum, of which 12,000 tons are consumed in the United Kingdom. It is supplied chiefly from Devonshire. Pipe clay is the result of the disintegration of granite, which is chemically a compound of alumina, silicic acid, and mica, and these three together constitute the earthy mass. The process was shown in action. A rough resemblance of a pipe having been formed of the clay, the stem has to be pierced; and it is here that all attempts to introduce machinery have failed, as the process depends solely on the touch. The end of the stem is held lightly between the forefinger and thumb, and a wire having a small button at the end is pushed gently in, and is guided by the sense of touch outside. The stem having been pierced, the pipe is placed in an iron mould, slightly greased, and the bowl is hollowed out by an iron pin forced in with a lever. Mr. Reynolds prepares the clay so as to make pipes surpassing meerschaum in whiteness, and purer and lighter than clay pipes hitherto produced.

CHAPTER VII.

SUNDRY MACHINES.

Mr. M. Lyons, Birmingham, exhibited a *magneto-plating and gilding apparatus*, with new

and cheaper solutions. He employs a horse-shoe magnet, having sixteen plates formed of bars $2\frac{1}{2}$ inches wide and $4\frac{1}{2}$ inches combined thickness, 2 feet long from the inside of the bend. This has been found by Mr. Lyons to be the most efficient size of magnet for the purpose. If the number of plates be increased, the increase of power is not in proportion; and if more power be wanted, it is better to put down two or more such machines side by side, and throw the two currents from them into one. Four pieces of soft iron are fixed upon a disc, and caused to revolve in front of, and just clear of, the ends of the magnet; they are covered each with a coil of 80 feet of wire; and by means of a break-wheel, positive and negative currents are produced, with four changes of current in each revolution. The positive pole gives a wire to the bath, and carries the piece of silver or gold as material for plating. The wire from the negative pole is connected to the object to be plated. The magnets, it is stated, have not varied in strength for eighteen years. Mr. Lyons employs a cheap solution at 2s. 6d. per gallon, said to be equally effective with the cyanogen solution at 10s. per gallon.

Magneto-electricity was first applied to electroplating by Mr. Woolrych, who, indeed, made the first application of that power to any useful purpose. Magneto-electricity is a constant force; whilst the power of galvanic batteries varies.

Messrs. W. Warne & Co., London, exhibited, in operation, their "*consolidated emery-wheels*," for grinding and polishing metals; they are 8 inches in diameter, and 1 inch thick, and are mounted on spindles in the manner of ordinary grinding-wheels, and should be moved at a circumferential speed of 6,000 feet per minute. The matrix employed for holding the emery is mineralized india-rubber. Another emery wheel was exhibited, composed of oxidized oil and emery, which also answered the purpose. These wheels are useful for removing the scale from forged or rolled iron, or cast iron, or steel, and are capable of cutting through steel bars.

M. C. Gustafson, Sweden, exhibited a *nail-making machine*, otherwise called a nail-rolling machine. This machine rolls, points, cuts, and heads the nails, and delivers them in one continuous process. One machine, with one attendant, is said to be capable of forming 12,000 4-inch nails, or 18,000 $2\frac{1}{2}$ -inch nails, in twelve hours, from small square bar-iron. The iron is heated only to a low heat, and is pushed in and withdrawn by hand, for successive rolling, and so as to make the nail square. Nails may also be made with fluted sides.

A *horse-shoe nail-making machine* was exhibited in the American department, having a vibrating anvil with a double alternating hammer, for striking alternately the side and edge of the nail. Four or five blows are required to form a nail.

M. J. E. Leonhardt, Berlin, exhibited a

machine for casting bullets for Minié rifle-guns. It is provided with a small furnace to melt the metal; six bullet-moulds are carried in a revolving frame, and, being in two halves, they are opened gradually by a circular inclined plane which acts on and pushes up a pin. The moulds clear the inclined plane, and are suddenly closed by springs just before they arrive in front of the tap from the furnace to receive the melted metal. Just before the mould closes, when it is most widely opened, the bullet previously cast in it drops into a spout. It is stated that the machine is capable of turning out from 1,800 to 3,000 bullets per hour, with the attendance of two men, and that it consumes half a ton of coal per day.

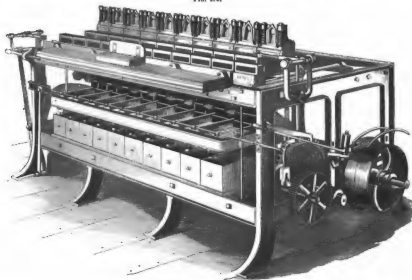
Mr. B. S. Cohen, London, exhibited his process of *manufacturing lead-pencils*, in which the

powder and fragments of the Borrowdale lead, from the Cumberland mines, after being pulverized and consolidated, are brought to a uniform consistency, and so formed into alips of unbroken length for insertion in the cedar. Good and serviceable pencils are thus produced.

Messrs. Morgan & Co., Paisley, exhibited a *machine for making shawl-pattern printing-blocks*, in which a hard printing surface is produced by the insertion of brass-wire pins into a prepared block of wood,—the effect of flowing lines being more or less perfectly produced, according to the fineness of the wire employed. The finest patterns have been executed by using wires 1-64th of an inch in diameter.

Mr. J. Wright, Kirkcaldy, exhibited an ingenious *mould-making machine for producing printing surfaces*. Moulds are produced, in the

FIG. 270.



REPEATING-ASSEMBLING MACHINE, by Mr. W. S. Yates, Leeds.

first place, by the action of finely-pointed tools, heated by a gas flame, which are made to burn into and char the surface of wooden blocks. Type-metal casts of the burnt-in pattern so obtained form the printing blocks. Two varieties of this machine were exhibited,—one producing a single impression, and the other capable of forming patterns on the upper and under surfaces of the wood blocks, by the simultaneous action of two heated points worked by one handle.

Messrs. W. Nightingale & Co., London, exhibited a *horsehair curling machine*. It is simple and effective: the curl, when given, being fixed by means of heat. The machine is

an improvement on the mode of curling horsehair by hand, in which a thick roving is spun of greater or less length, and then is further spun at a greater speed, to give the thread the form of a spiral rope. The curl impressed upon the hair in this way is fixed by heat, and the hair, being opened out, forms the elastic stuffing of chairs, sofas, mattresses, &c. The novelty in the machine consists in the process by which the operations of spinning the thread, and further twisting it into a spiral form, are simultaneous, whereas in hand-spinning they are separate and successive. A thread about $\frac{3}{8}$ -inch in diameter is formed by means of the revolving spindle round which it is passed,

and the additional twist, forming the spiral rope, is given by the flyer. In the preparatory stages the hair is formed into a sliver, as with hemp, by a spreader or carder; and is afterwards, if necessary, drawn to equalize the slivers. The bobbins are driven by coned pulleys. The frame contains only two spindles, and each spindle curls about 2 cwt. per day of ten hours.

Mr. C. Eastwood, Leeds, exhibited a *machine for cutting and measuring bass fibres*, and other substances, as drafts, kitool, whalebone whisks; in which a reciprocating knife, hinged at one end, is worked up and down against a fixed knife, by which the fibres are cut to lengths measured against a fixed gauge-plate.

Mr. W. S. Yates, Leeds, exhibited a *Bristle-assorting Machine*. The process of assorting bristles—which are to be found in commerce in mixed lengths,—into different lengths by hand, is tedious and imperfect. This machine is designed to supersede the hand labour; the bristles are placed in holders, twenty in number, and forming an endless chain, or double row, which is traversed by means of an intermittent motion, through the space of one bristle at a time. The holders may be described as wire brushes, and are placed in front of the machine. There

are ten pairs of nippers mounted in a rocking frame, one opposite each holder, and ranged side by side. After one or more reciprocations of the nipper frame, the holders are advanced one stage, so that each holder full of bristles is brought in front of successive nippers, which are so ranged as to be advanced successively $\frac{1}{4}$ inch nearer to the holder; and as the nippers open and close each time upon the longest bristles, they draw out and carry them back from the holders, and deposit them upon inclined spouts into receptacles below. Thus the bristles are assorted into lengths differing successively by $\frac{1}{4}$ inch. The machine, fed by two boys, efficiently performs as much work as could be done by eight men by the old process (fig. 270, page 295).

Messrs. G. Zanni & Co., London, exhibited a *self-basting meat screen*, which found its way into the machinery department. A jack or clock-work movement is fixed upon the top of the screen, by means of which the meat is turned, and at the same time a continual supply of dripping is kept falling upon it, by means of an endless chain with buckets to lift the dripping from the pan below to a gutter above, from which it is discharged upon the meat through a number of small holes.

IV.—MACHINERY IN GENERAL.

SECTION I.

STATIONARY AND PORTABLE STEAM-ENGINES AND BOILERS.

CHAPTER I.

INTRODUCTORY REMARKS.

AMONGST the great number of steam-engines exhibited, in the Western Annex alone,—about seventy-five in number, of which there were about sixty stationary engines, besides the display of engines in the Agricultural department,—the horizontal was the prevailing type of engine. The horizontal arrangement is obviously the simplest, the most compact, and the steadiest, other circumstances being alike; and, with compactness, it combines facilities for ready and minute supervision, and for general attendance and maintenance. The advantages of the horizontal system are so well understood, and the Exhibition showed that they were so generally acknowledged, that it is unnecessary now to say more for the system than to intimate the fact.

Of the exceptions to the horizontal arrangement, the most conspicuous were the beam-engines in the English section, constructed to work the sugar-mills. These magnificent specimens of workmanship have already been noticed in connection with the mills; and whilst it may perhaps be assumed that there is no decided advantage in the six-column beam-engine, for the performance of real work, over the horizontal engine—which is minus the beam,—it unquestionably commands the preference, in its superior presence and its graceful movements.

Whilst, in a very few instances, English constructors showed a desire to improve the economical performance of the steam-engine, their engines in general testified to a feeling of absolute indifference to economy of steam or fuel, and probably, in some instances, to ignorance of the conditions on which economical working is to be established. In one conspicuous instance,—a pair of high-speed horizontal engines, exhibited by Messrs. Gwynne & Co.,—the valves had been set without any lead, and the steam was

admitted up to the end of the stroke of the piston. The consequence was, that an enormous back-pressure—amounting to 40 per cent. of the whole positive pressure—was exerted against the piston, by reason of the difficulty of escape for the exhaust steam. The valves were, during the Exhibition, slightly readjusted, when the loss by back-pressure was reduced to from 25 to 30 per cent.,—still an excessive resistance. In another instance, that of Messrs. Burgh & Cowan's trunk-engine, the back-pressure amounted to 70 per cent.—nearly three-fourths—of the whole positive pressure.

The manifest concern of the foreign exhibitors to construct their steam-engines on economical principles, was, on the contrary, remarkable; and it is probably sufficiently accounted for by the costliness of fuel abroad. At home, nevertheless, they are sounding the alarm over our diminishing coal-beds; the key-note has been struck by Sir William Armstrong at Newcastle; and though eminent colliery-owners, as Mr. Nicholas Wood, do not apparently sympathize with Sir William, pointing with confidence to the vast unexhausted seams extending under the ocean, the alarm, well sounded, may do good, and cannot possibly do any harm. Of the two-and-thirty stationary engines exhibited in the English section, not more than half a dozen had clothing on their cylinders, and the most of these, remarkably enough, were clothed by the agricultural engineers. Nor is it too much to say that, taken generally, the engines exhibited by the agricultural constructors were better designed and detailed, and more thoroughly constructed, than those of most other engineers.

As the economizing of fuel in the working of steam-engines is likely to command greater attention than heretofore, it may be useful to consider, with the aid of the indicator, the behaviour of steam in the cylinder of an engine, with the conditions on which economy of steam is to be effected. Its action is fundamentally the same

with condensing as with non-condensing engines, the difference being chiefly in degree. The receptacle into which the steam from the cylinder is discharged is, in one case, the artificial atmosphere of the condenser, which exerts an absolute pressure of 1 lb. per square inch, less or more; in the other case, the natural atmosphere, having a higher absolute pressure of 14·7 lb., or, in round numbers, 15 lb. per square inch. The action of steam is developed in its most simple form in the non-condensing engine, in which the question of the vacuum has no part; and the Author will, therefore, proceed with a summary of his experimental investigations of the behaviour and condition of steam in non-condensing engines, chiefly of the locomotive class, first published by him in 1851, in "Railway Machinery," and subsequently in the article "Steam-Engine" in the last edition of the "Encyclopædia Britannica." Since the first publication of these investigations, comprising an experimental demonstration by the Author, of the great loss by condensation of steam in the cylinder when attempted to be worked expansively,—then demonstrated, he believes, for the first time,—the subject has been frequently revived. The Author's conclusions have been variously confirmed, and the necessity for the steam-jacket, or equivalent means of maintaining the expanding steam at a suitable temperature, is now generally accepted.

CHAPTER II.

THE INDICATOR-DIAGRAM—THE GENERAL BEHAVIOUR OF STEAM IN THE CYLINDER.

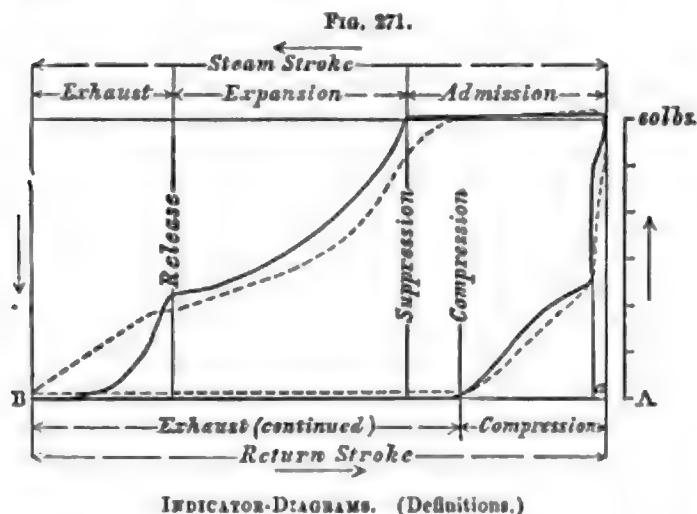
In illustration of the function and utility of the indicator, by means of which most of the Author's observations were conducted, examples of indicator-diagrams, obtained by him from one of the cylinders of a locomotive, are illustrated in fig. 271. The base-line AB is the line of atmospheric pressure, and represents the stroke of the piston; and the rectangular space above it may be supposed to be the interior of the cylinder. The heavily-lined figure is a diagram of the indicated action of the steam, when the piston moved in the cylinder at an average slow speed of 40 feet per minute, and shows by its angularity how the steam is controlled by the valve, and the precise points of the stroke at which the changes of the distribution take place. The piston is represented as having started from the right-hand end of the cylinder, under a uniform pressure of 61 lb. steam above the atmosphere, traced from the upper right-hand corner, till it reaches the point of suppression. The admission being terminated, the period of expansion is commenced, the pressure declines as the piston advances before the ex-

panding steam, and continues to do so till the piston reaches the point of release. At this point, the piston enters on its third and last stage of progress toward the end of the steam-stroke; the steam, primarily admitted at 61 lb. above the atmosphere, and attenuated to 23 lb. pressure previously to being released, quickly discharges itself into the atmosphere, in virtue of its remaining elasticity, and is entirely evacuated before the end of the stroke, as indicated by the quick and total decline of the steam-line during the period of exhaust towards the point B. The evacuation is, however, only relative, not absolute, as steam of atmospheric pressure remains in the cylinder, though not obviously sensible in the indicator-diagram; during the return-stroke, therefore, the valve ought to maintain the exhausted end of the cylinder continuously open, to allow the steam of one atmosphere to escape before the returning piston, and the benefit of this provision is proved by the diagram, in which it appears that during the continuation of the exhaust the steam of latent pressure remains at the zero point of the scale. At the instant of closing or compression, however, when there is no longer an exit for the latent steam before the piston, the diagram-line slopes upwards towards the right-hand side, and the steam is compressed against the end of the cylinder. While the volume of the compressed steam is being thus forcibly reduced, the density is increased, the pressure is raised, until the accumulation of back pressure so induced is merged into the superior pressure of the steam admitted by anticipation for the business of the next steam-stroke. The point at which this irruption of pressure occurs is indicated by the small compartment A in the figure, representing the "period of pre-admission," instantly the pressure mounts to the maximum initial pressure of 61 lb., in readiness for the succeeding steam-stroke.

The behaviour of the steam in the cylinder may thus, with the aid of the indicator-diagram, be clearly traced through the cycle of changes. The period of admission, in the example just described, is, it appears, about one-third of the whole stroke; that of expansion is something more, and a simple inspection of the diagram shows that, in this instance, one-half of the work of the steam is performed by simple expansion while shut up in the cylinder. Even the period of exhaust supplies its quota of effect, inasmuch as the evacuation is a work of time, and the extra positive pressure so yielded is represented by the small triangular space between the point of release and the end of the stroke. The force developed by compression is properly designated resistance, as it is opposed to the motion of the piston, and must be classed with the slight opposition also made by the entering steam during its pre-admission for the steam-stroke.

But the important inquiry remains to be urged,—How is the behaviour of the steam

affected by the speed of the piston? If the piston move slowly, there is plenty of time for the steam to go through its mechanical duties. While the steam is admitted, it follows up the piston at full pressure; while the exhaust is open, it thoroughly evacuates itself. But at higher speeds, the time for each evolution is proportionally shortened; and it remains to be considered in what way this acceleration of work is discharged. The dotted-line diagram (fig. 271)



illustrates the behaviour of the steam in the same cylinder, under the altered circumstance of a higher speed of piston, averaging 310 feet per minute, other circumstances being the same. The steam enters at an initial pressure of 62 lb. per square inch, but suffers a slight reduction of pressure as the piston recedes before it,—a circumstance which may at once be attributed to the accelerating speed of the piston in the cylinder specifically due to the nature of the crank-motion, and the consequently greater difficulty of following it. The difficulty, however, is not considerable, and it is only when the piston nears the point of suppression, and the port is nearly closed by the valve, that the pressure rapidly falls in the diagram towards the suppression-line. This is a case of simple wire-drawing, as the opening of the port, previously wide enough to admit all the steam that could find its way into the cylinder, against the frictional resistance and bends of the passage, is now reduced to the minimum width consistent with this condition, and a further contraction and final closing necessarily occasions an accelerated fall of the pressure. The pressure at the instant of suppression or cut-off, under these circumstances, is 54 lb. above the atmosphere. The curve descends during the period of expansion, and cuts the line of release at a pressure of 19 lb., and on reaching the end of the stroke, it attains a minimum of 2 lb. of pressure. The curve of expansion, it appears, runs into those of the admission and the exhaust, without any of the abruptness which distinguishes the slow diagram; the fact being that, before the steam was nominally cut off, expansion, technically so called,

had begun,—a result implied in wire-drawing; and there was, therefore, not the same liability to sudden change of pressure on entering the period of simple expansion. At the termination of the period of expansion, the curve crosses the exhaust line nearly at right angles, and barely reaches the minimum pressure at the termination of the stroke. The comparative delay so evinced in the accomplishment of the exhaust, is plainly a consequence of the shorter time allowed for this purpose by the greater speed of the piston; and, accordingly, one perceives a material accession to the area of the diagram, or the useful effect of the steam, in the very circumstance that it exhausts less freely. On the other hand, a drawback on this additional effect exists in the sustained back-pressure of 2 lb. per square inch, as indicated during the return-stroke, referable to the same cause,—imperfect exhaustion. The exhaust-line runs into the compression-line with a slight bend; and it is observable, that before the pre-admission takes place, the compressed steam attains to a higher pressure than that found by the slow diagram,—a circumstance to be explained by the condensation of steam in the cylinder at the low speed. But, though the curve of high speed is in advance of that of the low speed at the instant of admission of fresh steam, it falls behind at the commencement of the stroke. At this point the pressure does not get beyond 51 lb. above the atmosphere, and only attains the maximum, 62 lb., when the piston has described half an inch of the steam-stroke. This deficiency is attributable chiefly to the shortness of time allowed for the re-establishment of the working pressure, and indicates the need for more lead of the valve.

CHAPTER III.

THE BEHAVIOUR OF STEAM IN THE CYLINDER DURING ADMISSION.

In the flow of steam from the boiler to the cylinder, it meets with hindrances to its passage which usually operate to cause a considerable reduction of pressure when it reaches the cylinder, even if all the passages be thrown wide open. The actual charge of steam transmitted through an irregular passage of considerable length, and of a given sectional area, is, in all cases, less than what can be passed through an aperture of a very short length, as in a thin plate of the same sectional area, owing to the bends and lateral friction of the long passage. It therefore frequently happens that the opening of the port allowed by the valve, though it may be much less than the total area of the port, is sufficiently large to pass all the steam that can force its way along

the passage. This fact is constantly exemplified in practice; it is known that opening the port beyond a certain amount, in all cases less than the area of the port itself, ceases to be advantageous in facilitating the passage of the steam into the cylinder. Similarly, the opening of the regulator, or "throttle-valve," beyond a small fraction of the sectional area of the steam-pipe, does not add to the available pressure at the valve-chest. When the steam is not dry,—containing water in suspension,—the labour of moving in passages is greatly increased, owing to the quantity of dead, inelastic weight to be dragged along, and the reduction of pressure is consequently much more than with dry steam.

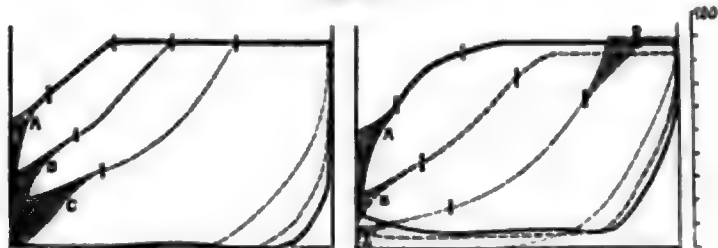
Directing attention, for the present, to the behaviour of steam within the cylinder, it is to be premised that, notwithstanding the objection that has been urged against the ordinary slide-valve, worked by an excentric-motion—the want of sufficient celerity of action,—there is no material wiredrawing of steam by the closing valve when the period of admission exceeds two-thirds of the stroke, unless at very high speeds of piston, exceeding 500 to 600 feet per minute. When the steam is cut off at shorter periods, however, the travel of the valve being less, and therefore, also, its velocity of motion, the wire-drawing increases at high speeds, though at low speeds it does not. For example, the indicator-diagrams (figs. 272)

the third case, with the shortest admission, the steam-line was practically straight and parallel to the atmospheric line, at speeds of piston up to 450 feet per minute. In inferiorly-arranged engines, with short lap and short travel of valve, wiredrawing is considerably greater than in the example just illustrated. With the same sizes of cylinders, a $\frac{3}{8}$ -inch lap wiredraws considerably more than 1 inch lap of valve.

Long lap, in conjunction with wide ports, reduces the wiredrawing to a minimum. The more dry the steam is, the more susceptible it is of apparent wiredrawing, as indicated in the cylinder, because dry steam enters the cylinder more freely than wet steam, and attains a higher initial pressure.

As to the quantity of lead of the valve needful to ensure ample and timely admission of steam into the cylinder at the commencement of the stroke, one-fifth of the length of the steam-port is sufficient. When the lead is excessive, the steam is admitted so readily as to be momentarily compressed, and to cause, in some cases, an unfavourable pulsatory action of the steam. The total absence of lead likewise occasions an unsteady pulsatory action in the cylinder. If lead is deficient or wanting, the maximum pressure of steam in the cylinder is not attained until after a portion of the stroke is traversed by the piston.

FIGS. 272.



INDICATOR-DIAGRAMS, to illustrate the behaviour of Steam in the Cylinder during Admission.

taken from a locomotive-cylinder 18 inches diameter, 24 inches stroke; steam ports, 13 by 2 inches; exhaust-port, 13 by $3\frac{1}{2}$ inches; lap of valve outside, $1\frac{1}{4}$ inch; inside, $\frac{1}{8}$ inch. Each figure shows three diagrams for periods of admission, respectively 16, $11\frac{1}{2}$, and 7 inches of the stroke, the terminations of which, and of the expansions, are pointed off on the figures. For the first figure, the speed of piston was 240 feet per minute; for the second, 770 feet per minute. The wiredrawing at the lower speed was obviously nothing; at the higher speed, the pressure fell 3 lb., 12 lb., and 25 lb. below the initial pressure before the steam was cut off. This shows that the wiredrawing increased very much in proportion as the steam was cut off earlier,—doubtless explained by the fact that, in the three cases, the travel of the valves was respectively $4\frac{1}{2}$, $3\frac{1}{8}$, $3\frac{1}{8}$ inches; and the maximum opening of the port was $1\frac{1}{8}$, $\frac{1}{8}$ nearly, and $\frac{1}{8}$ inch. It was found, however, that, in

CHAPTER IV.

THE BEHAVIOUR OF STEAM IN THE CYLINDER DURING EXPANSION.

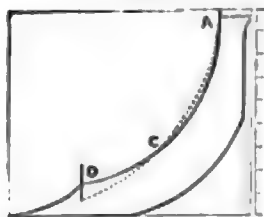
When steam is admitted into the cylinder, while the latter is comparatively cold, or colder than the steam, a very sensible condensation of the steam takes place during admission, in the process of heating the cylinder to the temperature of the steam, which continues to a certain extent during the period of expansion. A portion of this heat, though but a small part, passes off and is lost; the remainder is retained by the cylinder until it is re-absorbed by the precipitated steam during the expansion of the remaining steam, if it be long enough continued; that is, until the temperature of the latter falls below that of the cylinder. This is a destructive process, occasioning an absolute loss of steam; and the amount of steam thus injuriously precipitated, and but partially revived, increases rapidly in proportion as the steam is earlier cut off and expansion is extended. In the cylinders of ordinary steam-engines, the extra consumption and waste of steam devoted to the heating of the cylinder in the first part of the stroke is above 12 per cent. of the whole steam consumed, for a period of admission of one-third of the stroke. In exposed locomotive cylinders, the

loss is proved to amount to nearly 40 per cent. of the whole steam consumed, when cut off at one-eighth of the stroke.

This important species of loss is inseparable from the attempt to work steam expansively, where there is no provision for the heating of the cylinder, and maintaining it at a suitably high temperature,—equal, at least, to the initial temperature of the steam. The magnitude of the loss is so great as to defeat all such attempts at economy of fuel and steam by expansive working, and it affords a sufficient explanation of the fact, in engineering practice, that expansive working has been found to be expensive working, and that, in many cases, an absolutely greater quantity of fuel has been consumed in extended expansive-working, while less power has been actually developed.

With respect to the ratio of pressure to expansion of steam in cylinders, observed in ordinary practice, it may be sufficient to remark in this place, that the quantity or weight of steam in the cylinder is the same throughout the process of expansion, estimated in terms of the pressure and the volume of steam, as saturated at different points of the stroke, when the steam is dry, and the temperature of the cylinder is properly maintained; and that, consequently, the pressure of expanding steam in a cylinder, under such circumstances, may be determined with sufficient accuracy, for any degree of expansion, in terms of the ascertained density of saturated steam. On the contrary, in cylinders imperfectly heated, when the steam is partially precipitated during admission, and during the first part of the expansion, the expanding pressure at first declines more rapidly than would be due to the maintenance of a constant quantity of steam; and, afterwards less rapidly, rising above the expanding line of pressure proper for a constant weight of steam—equal to that contained in the cylinder at the commencement of expansion. This want of conformity is exemplified in a diagram taken from an outside-cylinder locomotive, with a stroke of 24 inches, at a low speed (fig. 273), in which the dotted

FIG. 273.



INDICATOR-DIAGRAM, to illustrate the behaviour of Steam in the Cylinder during Expansion.

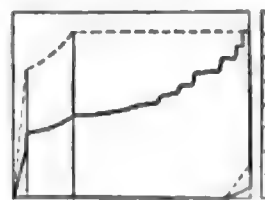
normal curve, until the temperatures of the steam and the material of the cylinder become equal, when, as the pressure continues to fall, and the temperature of the steam with it, the curve rises and crosses the normal curve at c,

in virtue of a partial re-evaporation of the steam previously precipitated, caused by the cylinder itself, which, at first colder than the steam, and heated by it in the first stage of the expansion, is then relatively hotter, and partially restores the heat of which it had previously robbed the steam. The process of restoration of heat goes on to the end of the expansion, as further proved by the increasing excess of the indicated above the normal pressure at the point D—amounting to above 10 lb. per square inch at the point of exhaustion.

That the condensing power of an unprotected cylinder is something very considerable, is rendered very obvious by an indicator-diagram (fig. 274), taken from the same cylinder, in full gear, at a low speed, shortly after starting with a train.

It shows that the pressure could not be maintained in the cylinder, as condensation in heating the cylinder proceeded faster than steam could be supplied through the opening of the port. Had the cylinder been hot, the pressure would have been fully maintained, according to the dotted line.

FIG. 274.



INDICATOR-DIAGRAM, to illustrate the Condensing Power of an unprotected Cylinder.

CHAPTER V.

THE BEHAVIOUR OF STEAM IN THE CYLINDER DURING EXHAUSTION.

In no part of the distribution is the advantage of time more apparent than during the period of exhaust. It is plain, by reference to figs. 271 and 272, that the steam does not discharge itself instantaneously from the cylinder at the point of release, as the piston, in all the diagrams, has visibly to go some distance before the pressure falls to a minimum. In fig. 271, at the lower speed, the piston moves $3\frac{1}{2}$ inches from the point at which the steam is released, to the point at which the pressure falls to the atmospheric line. At the higher speed, the steam only reaches the minimum pressure of 2 lb., when the piston has attained to the end of the stroke, through 5 inches of the cylinder. These are elementary proofs of the benefit of time for insuring a good exhaust.

As the velocity of steam, escaping uninterruptedly, would practically suffice to evacuate the cylinder in good time, to prevent the evil of back-pressure, there is no doubt that the back-pressure which does actually arise is owing to the circumstantial hindrance of mixed water, strictures, bends, and friction. The retarded motion of the piston towards the end of the stroke, in virtue of the action of the crank, is peculiarly favourable for the exhaustion of the

steam, as it allows time for its escape before the piston returns upon it. At the higher speeds, however, the escaping steam may be overtaken and driven before the piston into the atmosphere, should its remaining elasticity prove insufficient, and then an opposing back-pressure is established. The wider the lead for the exhaust, the less is the back-pressure, on account of the increased facility for escape. For the usual speeds of pistons of stationary engines—from 220 to 300 feet per minute,—the back-pressure is practically unimportant, if the cylinder be properly heated, and the steam dry. On the contrary, the back-pressure is very great when the steam is condensed within the cylinder, or if it be loaded with water by priming.

Fig. 275 shows, in contrast, the evil of condensation in a cylinder, in causing back-pressure.

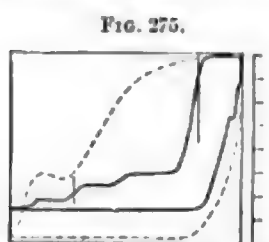


FIG. 275.
INDICATOR-DIAGRAM, to illustrate the behaviour of Steam in the Cylinder during Exhaust.

In the one case, the steam admitted at 80 lb. pressure above the atmosphere is cut off at one-sixth of the stroke, and exhausted at half-stroke; yet it is so loaded with water, when discharged, that it incurs a back-pressure of 12 lb. per inch in being expelled by the piston, moving at an average speed of 430 feet per minute. In the other case, illustrated in the same figure, the steam was admitted in a much greater volume, through half the stroke, at a speed of piston of 580 feet per minute, whilst the exhaust-pressure fell to about $2\frac{1}{2}$ lb. per square inch. The cylinder had been previously heated by hard work, the steam was comparatively dry, and the opposing pressure was, consequently, almost entirely removed.

The ordinary effect of the priming of muddy water from a locomotive boiler is illustrated by fig. 276, in which are shown indicator-diagrams taken from the cylinder immediately previous and subsequent to blowing off the boiler, when the water had been unusually impure, at the same speed of piston, about 600 feet per minute. The full line was described before, and the dot-line after, the boiler was supplied with clean water; and, other circumstances being the same, the back-pressure fell from 9 lb. to about $1\frac{1}{2}$ lb. per square inch above the atmosphere. In some cases the priming of water into the cylinder has been found to reduce the effective pressure more than a half.

The blast-pipe of locomotives should be larger in sectional area than the steam-passages in the cylinder, in order to discharge the steam with facility. The orifice of the blast-pipe should not be less, and it need not be greater, than the

smallest part of the passage from the cylinder; if smaller, it increases back-pressure.

Summary of data as to back-pressure.—If the steam, working in steam-engines, could escape freely without resistance, the back-pressure would be simply the pressure of the atmosphere, in non-condensing engines; and, in condensing engines, it would be the pressure corresponding to the temperature in the condenser—what Professor Rankine calls the “pressure of condensation.” The mean back-pressure, however, always—sometimes considerably—exceeds the pressure of condensation. One cause of this, in condensing engines, is the presence of air mixed with the steam, which causes the pressure in the condenser, and also the back-pressure, to be greater than the pressure of condensation of the steam. The ordinary temperature in the condenser, in proper working order, is about 104° Fahrenheit, for which the pressure is 1.06 lb. per square inch; whilst the actual pressure in the best condensers of ordinary engines may be scarcely ever less than 2 lb. on the square inch. The principal cause, however, of increased back-pressure is resistance to the escape of the steam from the cylinder, amounting to from 1 to 3 lb. per inch greater than the pressure in the condenser. There is no doubt that, practically, in condensing engines, the back-pressure increases with the speed of the engine, and also with the density of the exhausted steam, and with the size of the exhaust-ports. In non-condensing locomotive engines, the Author has found that the excess of back-pressure above the atmospheric pressure varies nearly as the square of the speed; as the pressure of the exhaust-steam at the commencement of the exhaust; and inversely as the square of the area of the orifice of the blast-pipe; that it is less, the greater the ratio of the expansion; that it is less, the longer the time during which the exhaustion of the steam lasts; and that it is increased by the presence of liquid water amongst the steam.

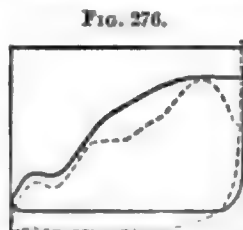


FIG. 276.
INDICATOR-DIAGRAM, to illustrate the ordinary effect of Priming in the Cylinder.

CHAPTER VI.

RELATIVE PRESSURES OF STEAM IN THE BOILER, THE VALVE-CHEST, AND THE CYLINDER.

As in the cylinder, so in the intermediate thoroughfares between that and the boiler, the movements of steam are affected by the conditions of dryness, as well as by the size and form of the passages. In well-protected cylinders, with dry steam, and ports one-fifteenth of the area of the piston, the fall of pressure, or wire-drawing, in the cylinder passages is about 16 per cent. of the pressure in the valve-chest, at a speed of piston of 600 feet per minute; and with a port one-tenth the area of the piston, the fall of pressure does not exceed 10 per cent. at

any speed. An example of the relative indicated pressures in the valve-chest and the cylinder of a locomotive is shown in fig. 277, where the

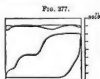


FIG. 277.
INDICATOR-DIAGRAM, TO ILLUSTRATE THE RELATIVE PRESSURES OF STEAM IN THE CYLINDER AND THE VALVE-CHEST.

former is represented to have oscillated above 5 lb. per square inch. In imperfectly protected cylinders, when the steam is not dry, the fall of pressure varies from 20 to 40 per cent. The fall of pressure in passing through pipes less than one-sixteenth of the piston in area, may be from one-third to one-fourth; in a pipe of one-tenth the piston, the fall is inconsiderable. If the steam be highly dried, a pipe of ordinary length, one-thirteenth the area of piston, is sufficient to transmit the steam undiminished in pressure.

The greatest useful opening of the regulator does not exceed one-twentieth the area of the piston. A greater opening is not found to add to the facility of transmission.

CHAPTER VII.

ORDINARY HORIZONTAL STEAM-ENGINES.

These engines are non-condensing, except when otherwise described.

Messrs. Barrett, Exall, & Andrews, Reading, exhibited one of their *high-pressure expansion and condensing engines*, of 30 nominal horse-power, employed in driving flax machinery (fig. 278). Considerable attention has been paid

in this engine, to insure economy of fuel, and at the same time simplicity of construction. The exhibitors guarantee the consumption of fuel of these engines at from 2½ lb. to 3 lb. of best Welsh coal per horse-power per hour,—a very important point when it is considered that as much fuel as this is consumed by the best-constructed high and low pressure cylinder-engines,

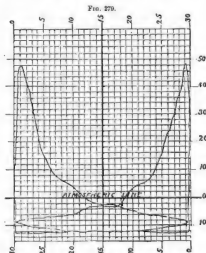
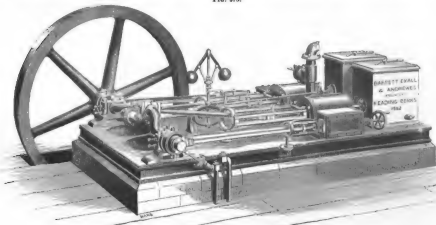


FIG. 279.
INDICATOR-DIAGRAMS, FROM ONE OF THE EXPANSIVE CONDENSING ENGINES OF MESSRS. BARRETT, EXALL, & ANDREWS. TO ILLUSTRATE THE ACTION OF THE EXPANSION-GEAR.

in which the steam is admitted at high pressure in the smaller cylinder, and passed into the larger cylinder at low pressure. This arrange-

FIG. 278.



30-HORSE-POWER HIGH-PRESSURE EXPANSION AND CONDENSING STEAM-ENGINE, by Messrs. Barrett, Exall, & Andrews, Reading.

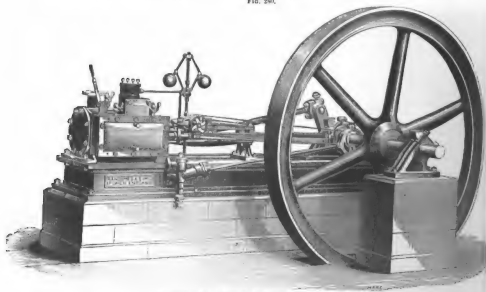
ment involves an expensive class of engines, which Messrs. Barrett, Exall, & Andrewes have in a measure superseded, by the employment of a cut-off valve, which is regulated by the amount of work on the engine. The bed-plate is planed perfectly true, and on it the cylinders, bearings, and condensers are fixed. The cylinders are steam-jacketed, and are in direct communication with the boiler, for the purpose of being maintained at as high a temperature as possible; they are $14\frac{1}{2}$ inches in diameter and have a 20-inch stroke. The double crank-shaft is made out of a piece of round iron bent to the shape, in order to insure the grain or fibre being in the direction of the strain. Each cylinder has a variable expansion-valve, independent of the main valve, capable of cutting off at a tenth of the stroke, the quantity of steam admitted by the expansion-valve being regulated by hand as the engine is working (see fig. 279). The piston-rods of the engines are prolonged through the covers, and work the air-pumps, which, together with the condensers and hot wells, are placed in line at the back of the cylinders. The entire condensers and air-pumps are submerged in the overflow water, which seals the joints, so that there need be no trouble in making air-tight joints. A vacuum of from 27 to 28 inches is frequently had in the condensers.

The same exhibitors showed a small *vertical engine*, neatly constructed, with an inverted cylinder, working to the crank below, employed to drive M. Bastien's chain-pump.

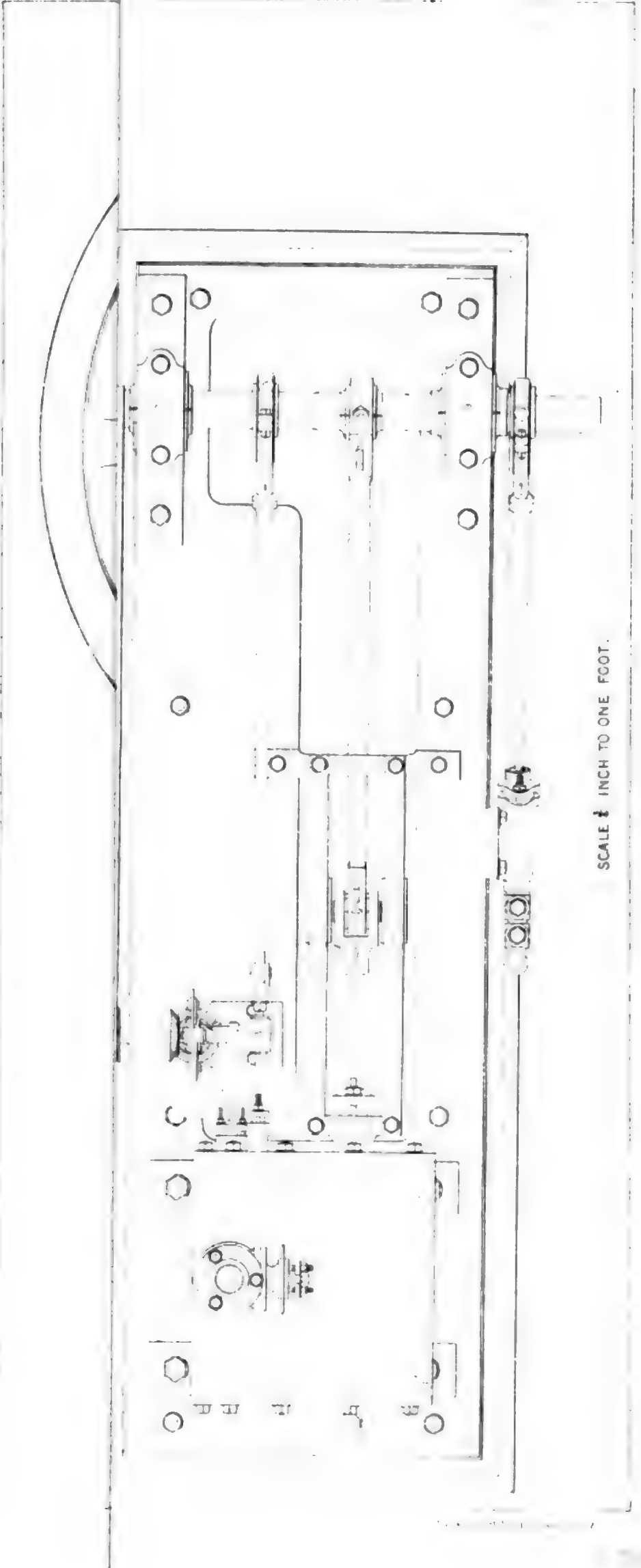
Messrs. Clayton, Shuttleworth, & Co., Lincoln, exhibited a *12-horse-power horizontal engine*, employed to work one of the two French pumps engaged in supplying water for the two large French fountains erected in the Horticultural Gardens. It has a single cylinder, 11 inches in diameter, with 16 inches stroke, non-condensing. The base-plate is planed on the upper and lower sides. The cylinders and the valve-chest are clad, and the engine is fitted with a feed-water heater, in which the water is passed in a jacket over a section of the exhaust-steam pipe, and is heated by superficial contact. The whole of the work is of the best description, and the engine is thoroughly finished. (Plate XXVII.)

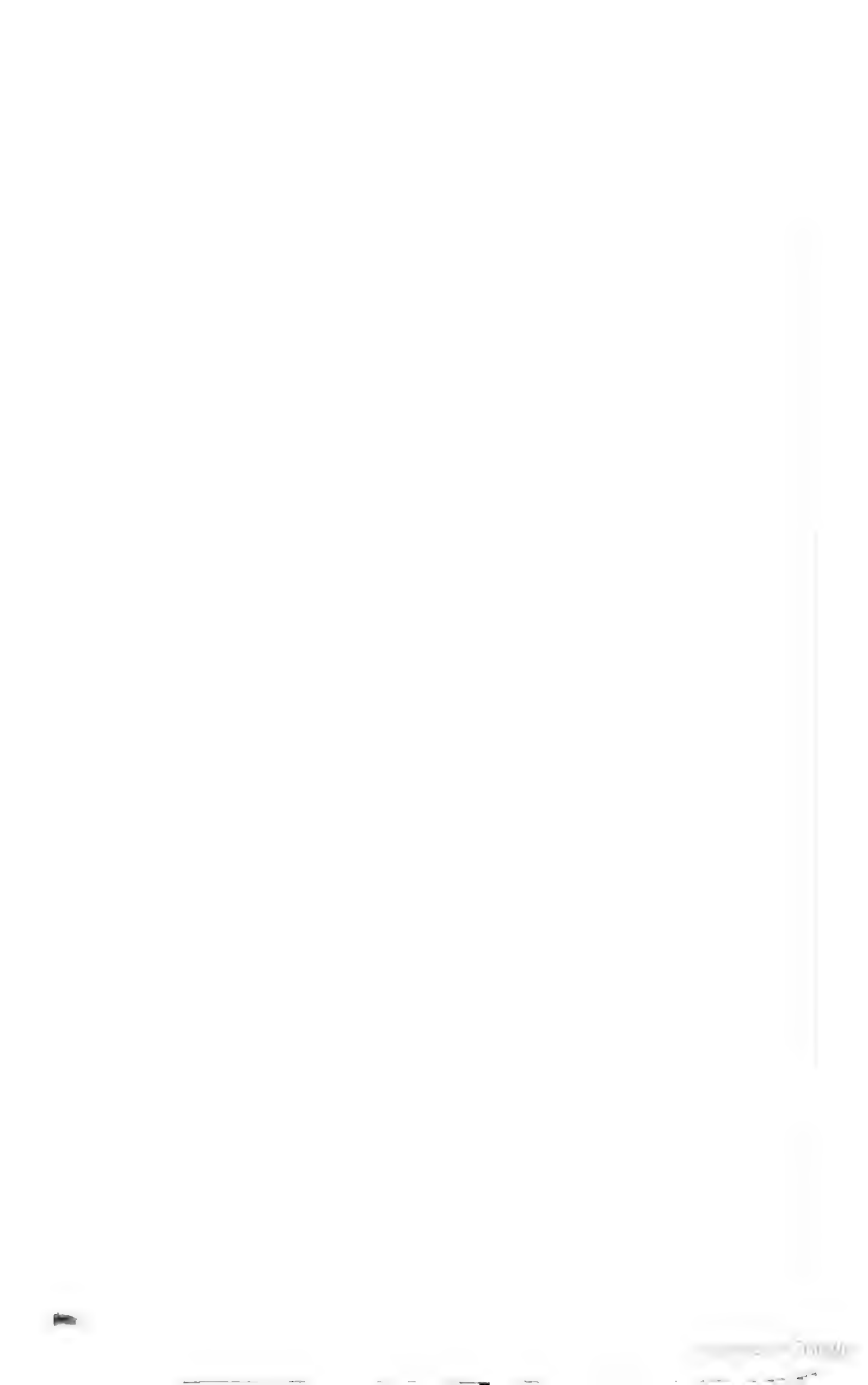
Messrs. Ransomes & Sims, Ipswich, exhibited two *horizontal steam-engines*, one of which has a 10-inch cylinder, with 16-inch stroke, and was applied to work a portion of the spinning machinery, and the other to work Messrs. Armstrong & Co.'s hydraulic crane, and other machines. One eccentric is employed to work two feed-pumps; one of these pumps is to lift the cold water to be heated by the waste steam, and the other to force the heated water into the boiler. The lower brass of the crank-shaft is let into the plummer-block with a circular seating; not being secured, it is liable to work loose. The bolts of the plummer-block are secured to it by three small tapered pins, instead of the usual cotter. The bolts and nuts through the connecting-rod end, to hold on the caps, are retained by means of a skewer passing right through them and the neck of the connecting

FIG. 280.



HORIZONTAL STEAM-ENGINE, by Messrs. Ransomes & Sims, Ipswich.





rod. The crosshead and slides are all in one piece, and the piston-rod is screwed into the crosshead with a lock-nut (fig. 280).

Mr. John Inray, London, exhibited three steam-engines in motion,—first, a *horizontal engine* of 20-horse power, with a 15-inch cylinder and 21-inch stroke, employed to work flax and woollen machinery; second, a *horizontal engine* of 7-horse power, with 9-inch cylinder and 12-inch stroke, employed in working the American carpet-loom, small printing-machines, &c. Mr. Inray was one of the earliest constructors of horizontal engines, eleven years ago. The frame is provided with two seatings for the plummer-block and the force-pump of the crank-shaft, so that it may be worked to the right or the left-hand side. The slides for the piston-crosshead are simply constructed, and consist of two lateral brackets bored out circularly, to receive the crosshead, which is finished in the lathe to slide between them. They are, with the obliquity of their wearing surfaces, more liable to wear slack than ordinary guides, but they are adjustable by means of set screws, and they possess the advantage that they permit the crosshead to yield without strain to the crank-shaft, should it be out of level for any reason. The valve-gear and the feed-pump are worked by one eccentric on the crank-shaft, the eccentric-rod being connected direct to the pump-plunger; and a link-rod from the eccentric-strap works the rocking-shaft for the valve-motion. By this plan, though simple, the valve-motion is more liable to slack action than when it is driven by an eccentric for itself. The crank-motion is received and transmitted by a cast-iron disc with a pin in it, instead of the ordinary crank. The third is a small *vertical engine*, with an 8-inch cylinder and 8-inch stroke; it was employed in driving woollen and flax machinery.

Messrs. B. Hick & Son, Bolton, had a *horizontal engine* at work, with one cylinder 14

inches diameter and 18 inches stroke, making 120 revolutions per minute; it was employed to drive the cotton and woollen machinery exhibited by Messrs. Platt Brothers & Co. It was of massive proportions and good workmanship, and was fitted with an equilibrium stop-valve.

Messrs. T. M. Tennant & Co., Edinburgh, exhibited a *6-horse power horizontal engine*, with 8½-inch cylinder and 20-inch stroke, employed in driving cotton-spinning machinery. The slide-valve is placed on the top of the cylinder, and worked by means of a rocking-shaft. The feed-pump is worked direct from the crosshead, and the valves are readily accessible. The cap of the plummer-block is held by four bolts; but two would be sufficient, and better.

Messrs. Wren & Hopkinson, Manchester, exhibited a *horizontal engine*, with a pair of cylinders 10 inches in diameter and 20 inches stroke, at work in driving their silk and cotton manufacturing machinery.

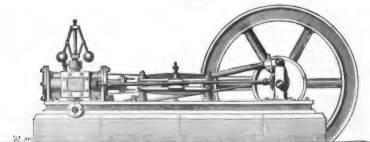
Messrs. Sandys, Vivian, & Co., Hayle, exhibited a *horizontal engine*, with a 14-inch cylinder and 24-inch stroke,—a substantial and durable engine.

Mr. J. Hands, Birmingham, exhibited a *2-horse power horizontal engine*, which was employed in driving an air-hammer. The crank-shaft runs in two bearings, wide apart, with a double crank in the centre; the crank, being at some distance from either bearing, is not properly supported. The engine otherwise is substantially put together.

Messrs. Bryan Donkin & Co., London, exhibited an *8-horse power horizontal engine*, for the purpose of driving the paper-making machinery they exhibited. It is a generally good, strong engine.

Messrs. Powis, James, & Co. exhibited a well-made *horizontal engine* (fig. 281).

FIG. 281.



HORIZONTAL STEAM-ENGINE, by Messrs. Powis, James, & Co., London.

Messrs. D. Napier & Son, London, exhibited a *horizontal engine* for driving their sugar centrifugal machine. It has not the appearance of an engine-builder's work. For example, the

stuffing-gland is screwed into the cylinder stuffing-box; the plummer-block is parted horizontally; the governor is driven by a gut-bund.

Messrs. Thornewill & Warham, Burton-on-

Trent, exhibited a pair of *horizontal colliery-winding engines*, as models of a class of powerful winding engines recently erected by them in the Midland Counties. There are two cylinders, which, in the model, are 12 inches in diameter, with 2 feet stroke; in the full-size engine they are made 20, 25, or 30 inches in diameter, with 5 feet stroke. They work to one crank-shaft, on which, in some engines, a fly-wheel is fixed; and the rope-drum is fixed on the same shaft. With the two cylinders, the counterbalance-chain is dispensed with. The drum is made from 12 to 16 feet in diameter, to hold 500 yards of rope and upwards. The engines are usually made with double-beat valves, easy to work; but the engine exhibited is fitted with overhung valve-gear on the outer sides of the cylinders, with double eccentrics and locomotive link-motion for ready reversing. There is only one handle to work, and that is for the valves; the break is worked by the foot. The engine usually makes

steam, the engines are capable of raising 1,000 tons of coal in a day. By the use of a pair of cylinders, the winding motion is uniform, and obviates the continual check or fluctuation of speed incidental to the action of a single-cylinder winding-engine, and injurious to wire-ropes.

CHAPTER VIII.

ORDINARY VERTICAL AND BEAM ENGINES.

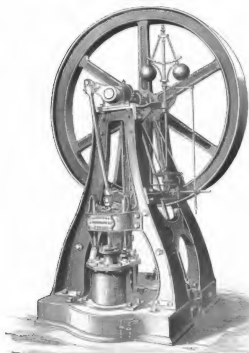
Messrs. J. Ferrabee & Co. (now the Phoenix Iron Works Company), Stroud, Gloucestershire, exhibited a *vertical steam-engine*, with the crank overhead. It has a separate expansion piston-valve, working in a chamber behind the ordinary slide, controlled by the governor, which acts upon a link-motion worked by two eccentrics, as in locomotives, and on the principle of Allan's straight-link motion. The cylinder, 10 inches in diameter, with 18-inch stroke, is fitted with a steam-jacket cast upon it. The exhaust steam is discharged into a cistern formed in the base, to heat the feed-water. This is a neat, well-arranged, and serviceable engine. It was applied to drive the wood-working and the printing machines (fig. 282).

Mr. W. Benson, Nottingham, exhibited a *vertical engine*, with the crank overhead. The whole engine stands on a planed base-plate,—a round column being placed beside the cylinder, to carry the crank-shaft. The governor is placed on the top of the column, with a bearing in a deep socket, and is compactly driven from the crank-shaft by means of skew-gear pinions at right angles. It is a simple, neat, accessible, and serviceable engine for small sizes (fig. 283).

Messrs. Williamson Brothers, Kendal, exhibited a *vertical column engine*, with crank overhead, in which the cylinder is fixed within the base of a column which is open at four sides, and answers the purpose of a frame, equally stiff in every direction, and combining strength with lightness. The engine is fitted with an equilibrium throttle-valve, controlled by the governor, and designed with

flanges or rings, to prevent its sticking in any position. The governor can be disconnected instantly by means of a lever, by which the steam is shut off at the same time (fig. 284).

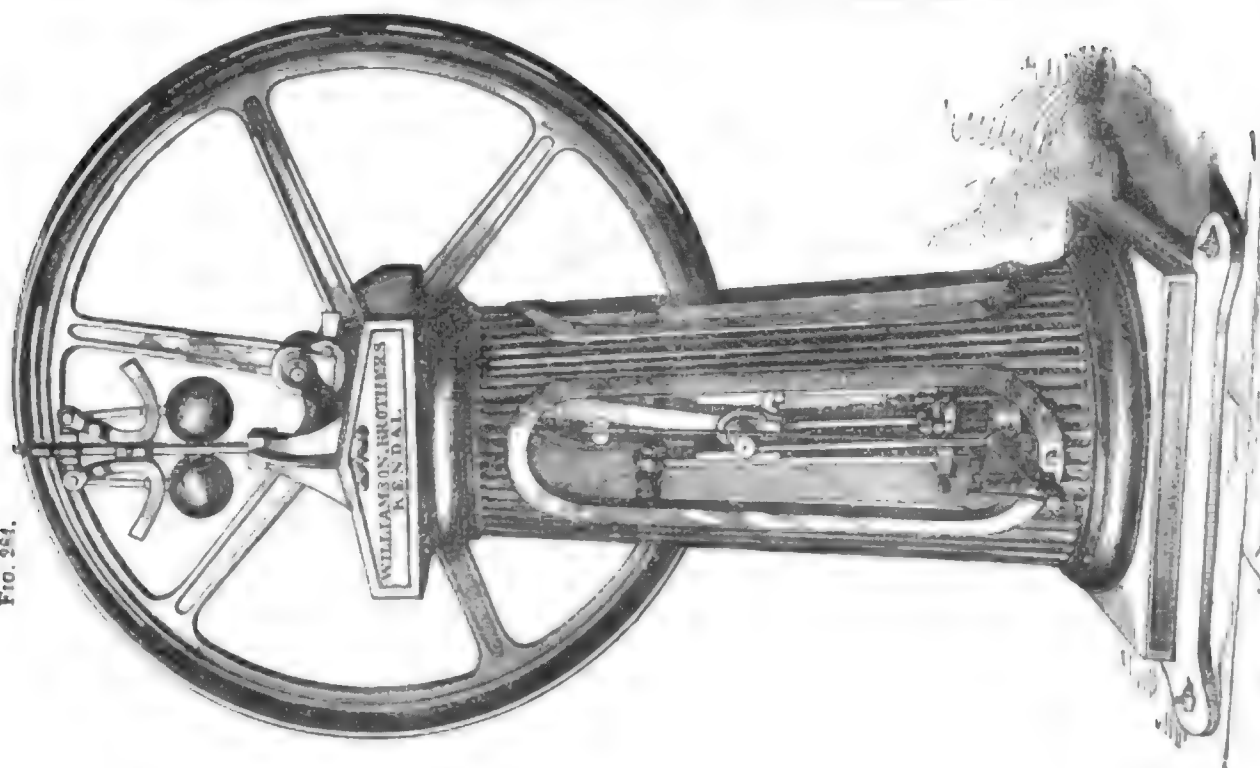
FIG. 282.



VERTICAL STEAM-ENGINE, by Messrs. Ferrabee & Co., Stroud.

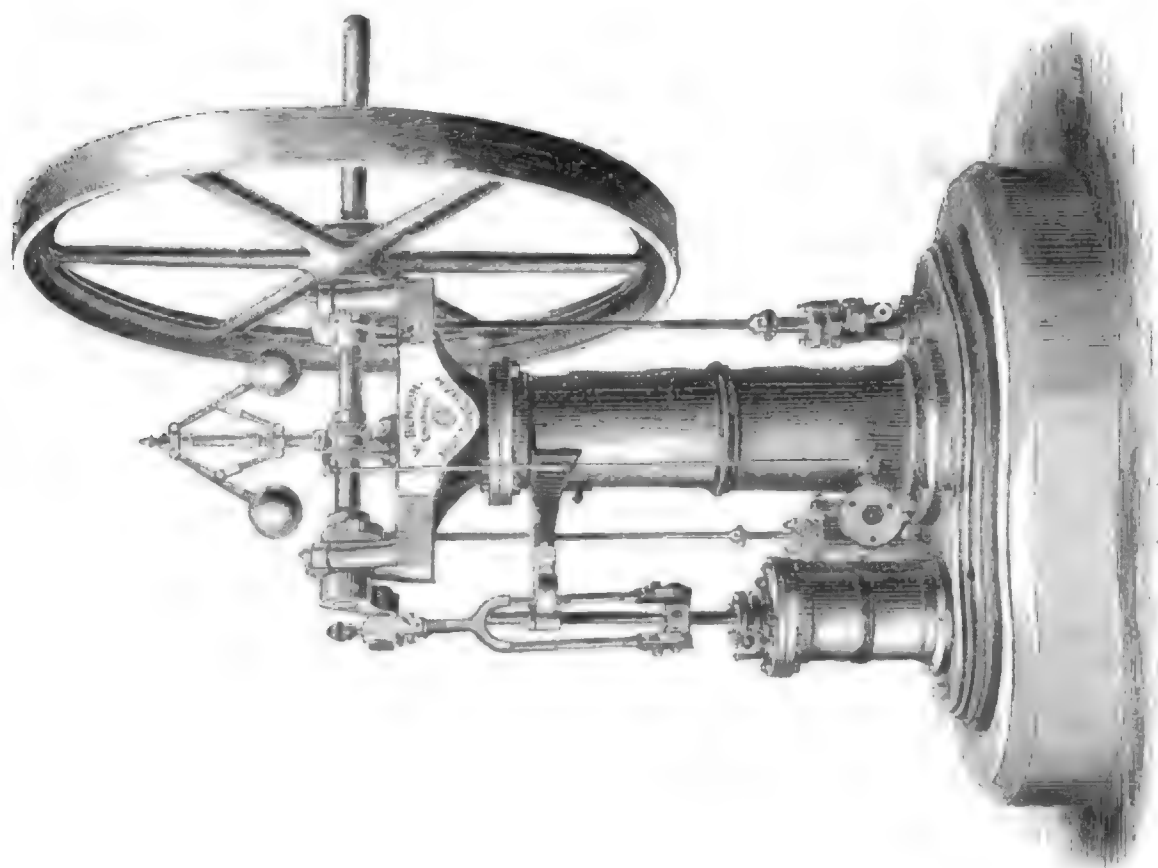
from fifteen to twenty revolutions in a lift; it can be stopped within half a turn, going full speed. It would send 500 yards of rope down the pit in a minute, with a 16-foot drum. With 40 lb.

FIG. 284.



VERTICAL COLUMN STEAM-ENGINE, by Messrs. Williamson Brothers, Kendal.

FIG. 283.



VERTICAL STEAM-ENGINE, by Mr. W. Benson, Nottingham.

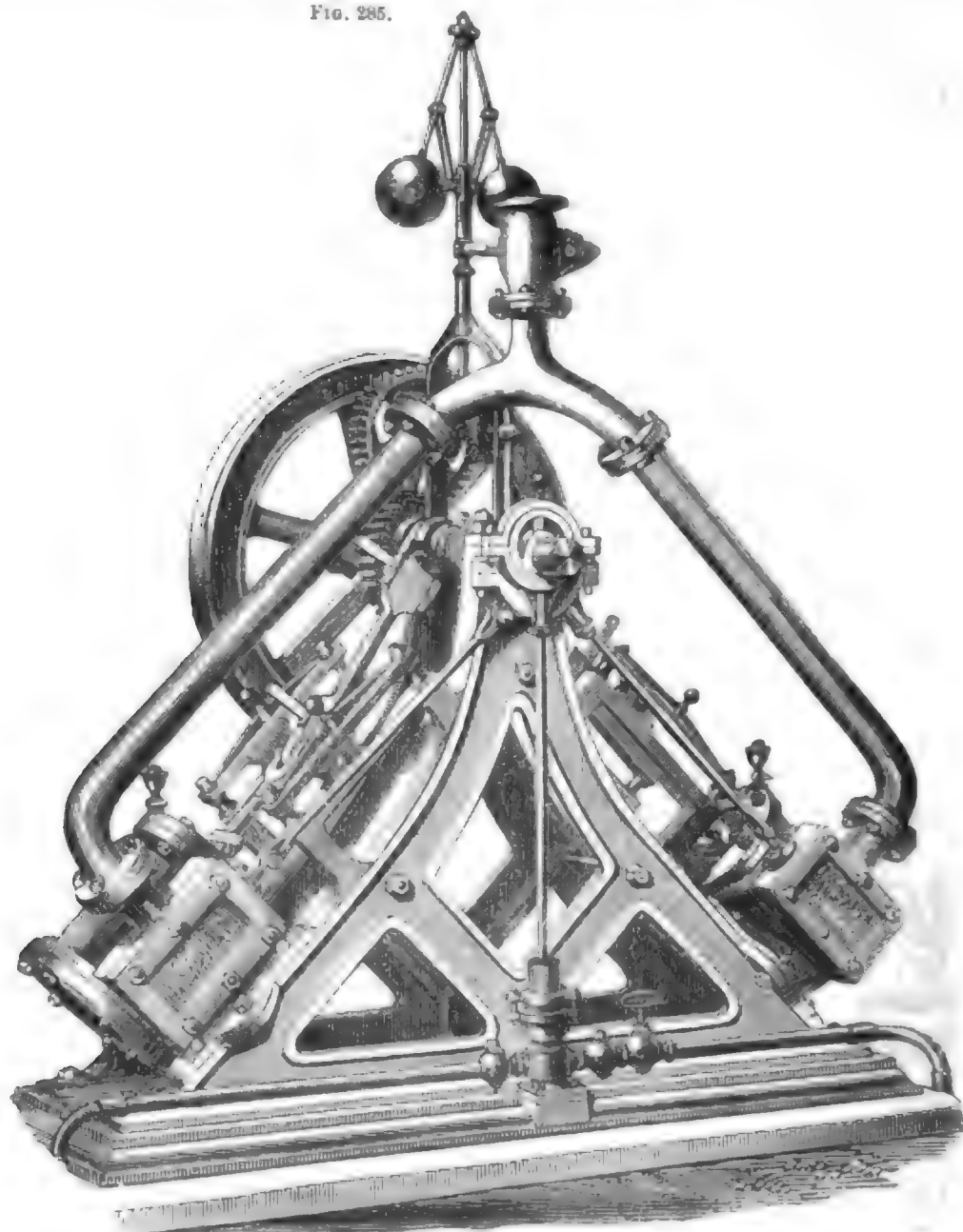
Messrs. Routledge & Ommanney, Manchester, exhibited a *diagonal engine*, with two cylinders 8 inches in diameter, with an 8-inch stroke, inclined at right angles to each other, working to a single crank on the shaft overhead, on a diagonal frame, entirely self-contained. The engine was designed specially to drive calico-printing and calendering machines. The governor is fixed upon the cover of the plummer-block,—scarcely correct practice. The engine was employed to drive cotton-spinning machinery. The

same exhibitors showed a boiler-feeder, a feed and fire-engine, and a magnet-machine, which will be noticed in their proper places (fig. 285, page 308).

Messrs. Belliss & Seekings, Birmingham, exhibited a $2\frac{1}{4}$ -horse power *vertical engine*, with the cylinder inverted, and working to the crank-shaft with bearings on the base-plate. It is an example of a class of engines constructed on the same general design, up to cylinders of 36 inches in diameter. For large power it is perhaps the

x 2

FIG. 285.



DIAGONAL STEAM-ENGINE, by Messrs. Routledge & Ommauney, Manchester.

steadiest form of vertical engine. The engine was neatly designed ; it was employed in driving small tools (fig. 286).

Messrs. Carrett, Marshall, & Co., Leeds, exhibited a simple form of *vertical engine*, with inverted cylinder, on which plan engines of from 1 to 20-horse power are constructed. To obviate the usual objection to inverted cylinders from leakage through the stuffing-box at the bottom of the cylinder, the stuffing-box is projected for its whole depth, upwards into the cylinder, a corresponding recess being formed in the piston, so that leakage from the cylinder is prevented. Variable expansion-gear is also applied, with a constant free exhaust (fig. 287). 2. The same form of engine fixed upon a vertical boiler, which forms a foundation for the engine. The inside of the boiler is accessible by a man-hole, for cleaning out, and the boiler is entirely constructed of boiler-plate flanged and welded, with an internal fire-box, hanging water-chamber, and

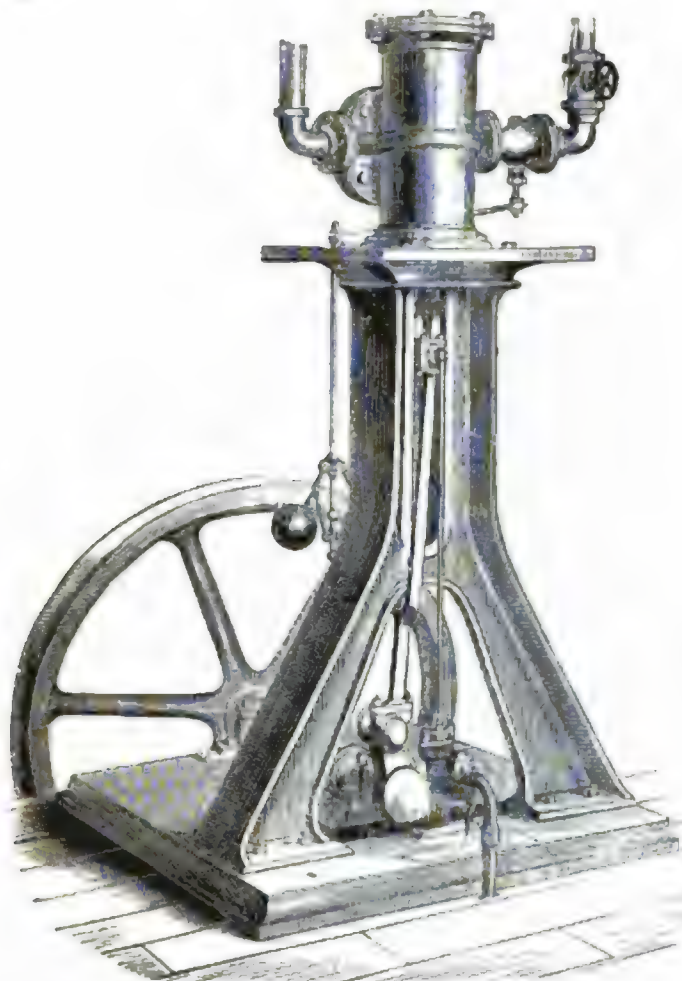
uptake (fig. 288). The horizontal engine exhibited will be noticed in the following chapter.

Messrs. R. Wood & Sons, Leeds, exhibited a condensing beam-engine, with two cylinders on Woolf's system, having a double A frame to carry the bearings of the beam, supplemented by a pair of slight columns at each end of the base-plate, with an entablature. The A frame is the really useful part of the upper structure. The bearings of the parallel motion are set up on the old Leeds fashion, by set-screws. The cast-iron connecting-rod is good, and cheaper than one of wrought iron. The excentric rod is expensively framed, as Murdoch did forty years ago. The engine was employed in working the brick-making machines.

The Lilleshall Company, Shifnal, Shropshire, exhibited a pair of condensing *blast-engines*, having two upright steam-cylinders 20 inches in diameter, and two 44-inch blast-cylinders, at the opposite ends of beams, which are inge-

niously made to overhang the blast-cylinders, to work by connecting-rods to a fly-wheel shaft. They are capable of blowing two cold-blast

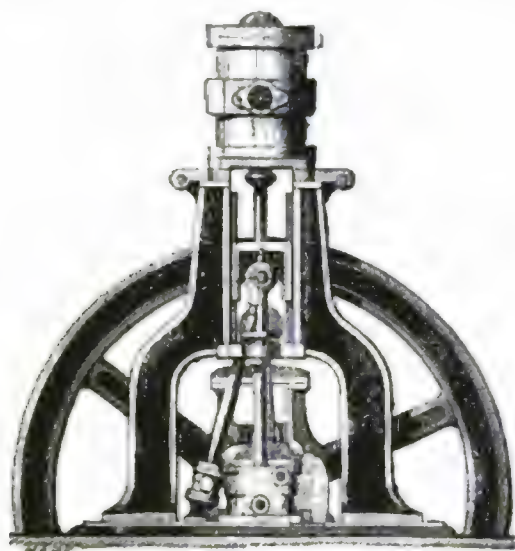
FIG. 286.



VERTICAL STEAM-ENGINE, by Messrs. Belliss & Seekings, Birmingham.

furnaces, and were placed on wrought-iron foundations for convenience of exhibition. They are fitted with four double-beat valves and

FIG. 287.

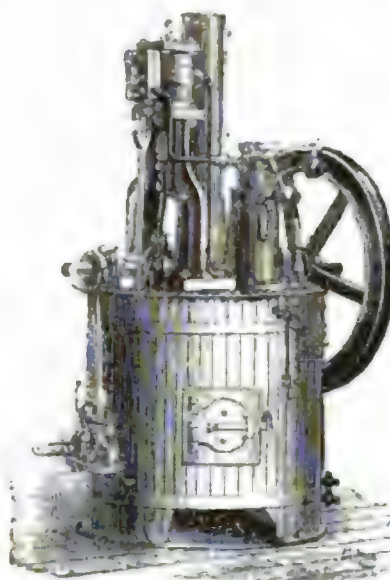


VERTICAL STEAM-ENGINE, by Messrs. Carrett, Marshall, & Co., Leeds.

expansion-gear, working direct. The "Lodge" blast-engines, arranged like those exhibited, have 40-inch steam-cylinders, and 86-inch blast-

cylinders, with $8\frac{1}{2}$ feet stroke make twelve revolutions per minute, and produce a blast-pressure of $3\frac{1}{2}$ lb. per square inch. With 30 lb. steam in the boiler, they cut off at one-third of the stroke in the steam-cylinders, and with a pressure of from 15 lb. to 17 lb. above that

FIG. 288.



SEMI-PORTABLE VERTICAL ENGINE, by Messrs. Carrett, Marshall, & Co.

of the atmosphere, they consume $4\frac{1}{4}$ cwt. of coal per ton of pig-iron manufactured. The engines exhibited were admired for their fine proportions and their excellent workmanship (figs. 289, 290, pages 310, 311).

Several steam-engines were exhibited in special connection with and driving other machinery for various purposes; these, if not elsewhere described, are noticed with the machinery to which they are attached.

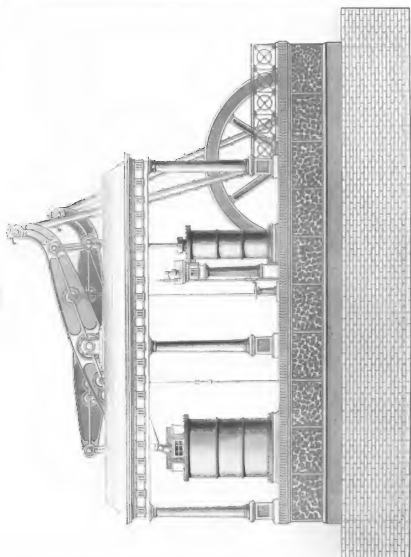
CHAPTER IX.

STEAM-ENGINES SPECIALLY DESIGNED FOR EFFECTING ECONOMY OF FUEL.

Certain English constructors, sensible that economy of fuel is a consideration of practical importance, have directed their attention to the means of effecting economy, in the disposition of steam-engines. The most prominent is the construction of horizontal engines with two cylinders, so arranged that the steam, after having been more or less expanded in the smaller cylinder, is further exhausted into and worked in the larger cylinder.

Messrs. Carrett, Marshall, & Co., Leeds, exhibited a simple, well-made, and ingeniously designed *horizontal double-cylinder engine*, with two cylinders, respectively $12\frac{1}{2}$ and 21 inches in diameter, with 27 inches of stroke. They are placed side by side on one base-plate, and work to

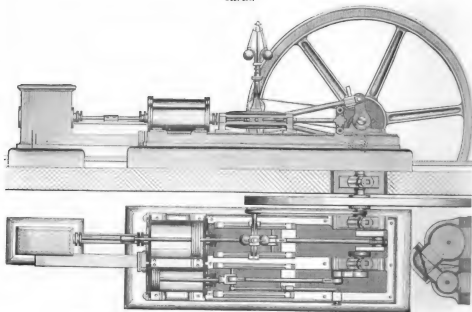
FIG. 260.



cranks diametrically opposed, on the same shaft. Thus the pistons do not, as has been usual in compounded twin-cylinders, work together on the same cross-head, making their forward and backward strokes together; but they alternate, and by this disposition the steam is exhausted by the medium of a single slide, straight across from each end of the high-pressure to the same end of the low-pressure cylinder, through the shortest possible passage. Thus, also, the reciprocating

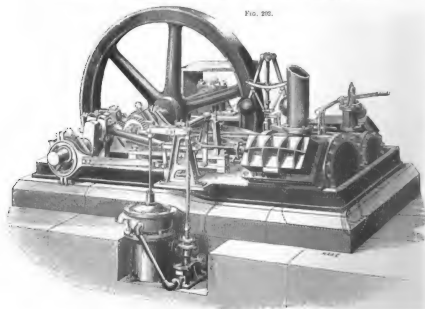
mechanism balances itself, and a perfectly steady motion is obtained. By the cross-sectional figures it is shown that the valve-faces of the cylinders are at right angles to each other, connected by a single slide, and are at 45° with the horizontal plane of the cylinders. The air-pump, which is double-acting, and the condenser, are placed apart, behind the low-pressure cylinder; the pump is within the condenser, and is worked by a prolongation of the low-pressure piston-rod.

FIG. 201.



DOUBLE-CYLINDER EXPANSIVE HORIZONTAL STEAM-ENGINE, by Messrs. Carruth, Marshall, & Co., Leeds.

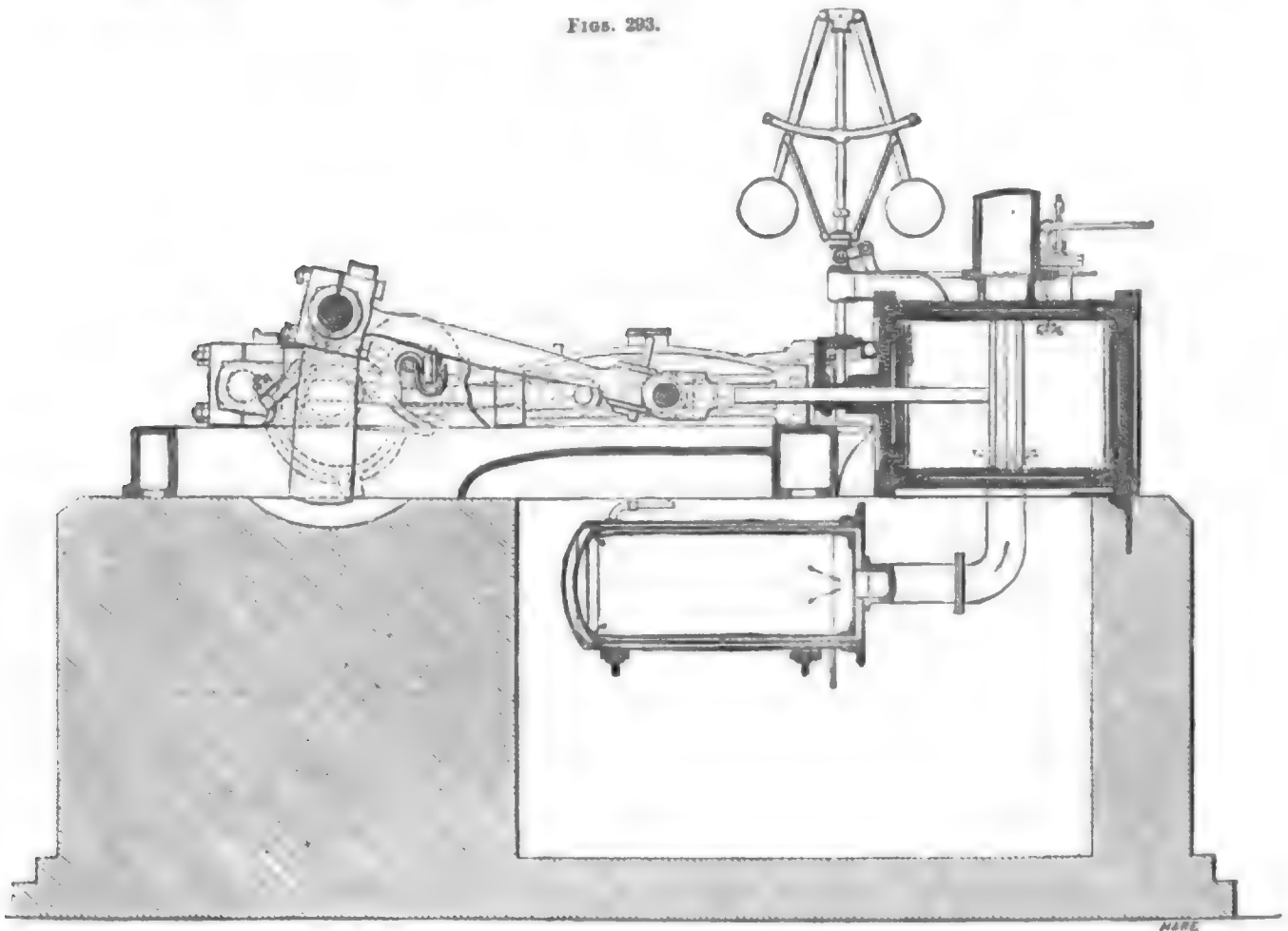
FIG. 202.



DOUBLE-CYLINDER EXPANSIVE STEAM-ENGINE, by Messrs. Walter May & Co., Birmingham.

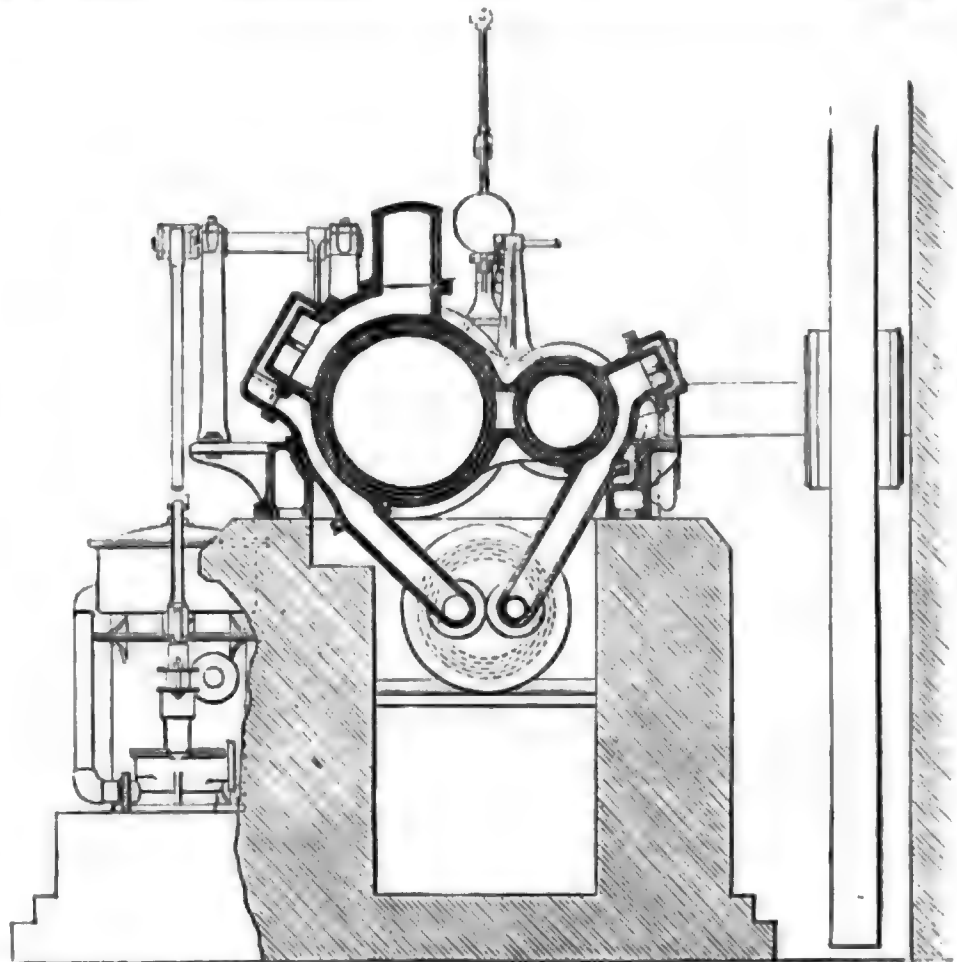
designed to be set free,—before the smaller piston reaches the end of its stroke. The slide valve, which serves both cylinders, has two faces, and the lead and travel may be varied.

FIGS. 293.



Messrs. Walter May & Co., Birmingham, exhibited a *horizontal double-cylinder engine*, with the cranks at right angles, designed especially with a view to obtain uniform rotative power, and at the same time to carry the expansion of the steam to a great extent, for the purpose of insuring the utmost amount of economy in fuel.

The cylinders are respectively 10 and 21 inches diameter, and the length of stroke is 2 feet in each case; one external steam-jacket, fed direct from the boiler, embraces both cylinders. The steam enters the smaller cylinder at the full pressure of the boiler, and when the



DOUBLE-CYLINDER EXPANSIVE STEAM-ENGINE, by Messrs. Walter May & Co. (Sectional Views.)

piston has travelled half its stroke, is cut off and expanded through the remainder of the stroke. It is then exhausted into the wrought-iron reservoir under the bed-plate, this reservoir being jacketed with high-pressure steam from the boiler. Here the steam is stored up until the crank of the larger cylinder, which is at right angles to that of the smaller one, has brought its piston to the end of the stroke, when the slide-valve of the large cylinder opens and admits the steam from the above-mentioned reservoir, and, as in the smaller cylinder, it is again cut off at half-stroke, expanded through the remainder of the stroke, and exhausted into the condenser, which may either be a surface-condenser, as in the case of the engine exhibited, or an ordinary one, according to the circumstances of each particular case. The air-pump, which is placed vertically, as being preferable to horizontally, is worked by a connecting-rod from the end of the cross-head of the large cylinder (figs. 292, 293, pages 312, 313).

The steam is, in the first place, expanded in the smaller cylinder to double its volume, and after having passed through the intermediate reservoir, is admitted into and cut off at half-stroke in the larger cylinder. As the larger cylinder has four times the sectional area of the smaller, the steam is by that process submitted to an expansion amounting to nine times its original volume.

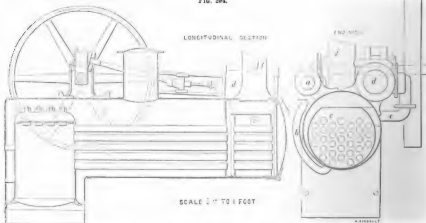
The exhibitors remark, that "the nearest approach that it is possible to obtain to perfectly uniform rotative power, is arrived at by constructing, from calculation, the indicator-figure

that would be produced by each cylinder, and deducing therefrom the requisite proportions that should exist between their two diameters, and the points at which the steam should be cut off, in each respectively."

In connection with the above-described engine is exhibited Perkins's surface-evaporator condenser, consisting of a number of upright tubes closed at their upper ends, and exposed to the atmosphere, or to a water-condensing medium. The steam to be condensed is exhausted into the tubes.

Mr. F. H. Wenham, London, embodies the same principle of action in his *semi-portable "thermo-expansive steam-engine,"* exhibited with its boiler, in the form of a portable engine. There are two cylinders, of different diameters, working directly to cranks at right angles on one shaft. Steam of 100 lb. pressure is admitted from the boiler to the smaller cylinder, 5 inches in diameter, with 12 inches stroke, and thence exhausted into an "interheater," where it is dried and superheated, and greatly augmented in volume; thence it is conveyed into the larger cylinder, 8½ inches in diameter, having three times the sectional area of the smaller, and finally exhausted into the chimney. The heating chamber has about a hundred times the capacity of the larger cylinder; so that a nearly uniform pressure is obtained upon the larger piston during its stroke. The chamber is placed within the smoke-box, and is detached from the boiler. It is formed with a series of flue-tubes, so placed as to be coincident with those of the boiler (fig. 294).

FIG. 294.



SEMI-PORTABLE THERMO-EXPANSIVE STEAM-ENGINE, by Mr. F. H. Wenham, London. (a, smaller cylinder; b, pipe from it to the regenerator c; and c, pipe from regenerator to larger cylinder, d; f, blast-pipe.)

The design of this engine is, then, to communicate heat to the steam during its expansion, and in its passage from the smaller to the larger

cylinder. That it operates with a certain degree of efficiency is apparent from the fact that whilst the steam from the relief-cock of the

smaller cylinder is mixed with water of condensation, that from the larger cylinder is perfectly dry and nearly invisible. If the steam be cut off and expanded in the first cylinder down to a terminal pressure equal to the back-pressure from the interheater, there is not, abstractly, any material loss of useful effect from this source. In fact, Mr. Wenham's object is to make the interheating chamber as capacious as possible. In the ordinary compound engine, as he remarks, there is a loss of effect in the emptying and refilling of the intermediate passages—an objection which does not apply either to his engine or to that of Messrs. May & Co.

The boiler attached to the engine has 74 square feet of tube-surface, and 8 square feet of firebox-surface; making a total of 82 square feet, with 2·36 square feet of grate. The working pressure in the boiler is 100 lb. per inch, and the engine makes 120 revolutions per minute. It was found in one trial, which appears to have been carefully made, that the engine exerted $10\frac{1}{2}$ -horse power at the brake on the fly-wheel, with a gross consumption of 210 lb. of coal, including 30 lb. to get up steam, and an evaporation of 26 cubic feet of water, in six hours, or $7\frac{3}{4}$ lb. of water per lb. of coal. The consumption of coal per horse-power at the brake was 3·33 lb., including the coal for getting up steam, or 2·85 lb. exclusive of that.

Mr. Wenham states that, practically, his interheater does not get injuriously hot, except when there is a bright fire and the engine is at rest; for the steam exhausted from the first cylinder takes up the heat with avidity. An engine on his principle has been at work for eighteen months on his premises, giving out 3-horse power by the friction-brake applied at the rim of the fly-wheel, and consuming 90 lb. of fuel per day, or one ton per month. Since the larger cylinder was added to the engine,—originally made with but one cylinder,—the puffs of the exhaust steam, formerly very noisy, have become nearly silent.

A similar engine, in all respects the same in dimensions, with the exception of the grate, which had 2·64 square feet of area, was submitted for trial. The interheater or “regenerator” had 25 square feet of surface, and 16 cubic feet of capacity. The results of ten hours' continuous working showed an exertion of 16·05 indicator horse-power, with a consumption of 2·1 lb. of coal per horse-power per hour. Of the 16-horse power, the first cylinder contributed 7·77-horse power, and the second 8·28-horse power—nearly equal proportions. With 100 lb. steam in the boiler, the maximum pressure in the first cylinder was from 97 to 98 lb. per square inch. The back-pressure in the same cylinder was 27 lb., and the positive pressure in the second cylinder was $23\frac{1}{2}$ lb. Thus, a fall of pressure amounting to $3\frac{1}{4}$ lb. per square inch appears to have taken place in the transit from

the first to the second cylinder. The regularity of the back and positive pressure-lines in the first and second cylinders respectively, proves the equalizing action of the intermediate chamber.

Mr. W. P. Wilkins, Ipswich, exhibited a 20-horse power *condensing steam-engine*. It has two cylinders, $8\frac{1}{2}$ and 10 inches in diameter, placed one above the other, end to end, for working the steam expansively from the upper into the lower. There are two piston-rods from the lower cylinder, which pass up and work within tubes cast on the sides of the upper cylinder. The piston-rods are attached to one end of a beam which rocks on its other end, with an intervening connecting-rod to the crank. A tubular feed-water surface-heater is applied between the larger cylinder and the condenser, through which the feed-water passes to the boiler, after leaving the feed-pump. The engine, it is alleged, will drive six pairs of four-feet mill-stones, with a consumption of 2 lb. of coal per indicator horse-power per hour.

CHAPTER X.

SUNDRY STEAM-ENGINES.

Messrs. J. W. Gray & Son, London, exhibited a “*spherical steam-engine*” in operation, consisting of two globes 15 inches in diameter, within each of which a piston or leaf, fixed on a central boss 10 inches in diameter, vibrated on a rocking-shaft, and, by means of an external lever, transmitted the motion to a horizontal crank-shaft by a connecting-rod. The professed object in this engine is to gain a greater degree of efficiency than in ordinary engines, by means of leverage. With vast areas of rubbing surface and radiating surfaces, and the hopelessness of the old-fashioned mechanical fallacy involved in the machine, it could scarcely do more than move itself; and, upon the whole, it fairly embodied steam in agony.

Messrs. Bunnett & Co., London, exhibited their good old *concentric engine*, in which there are two pistons rocking upon a central shaft, within a cylinder, and central with it. The engine was applied to work Lloyd's fan, and also to show Messrs. Bunnett & Co.'s brick-making machine in motion, which it did very well.

Mr. J. Davis, Ulverston, exhibited Davis & Evans's “*fixed-valve oscillating engine*,” with an oscillating cylinder, intended to obviate the objections to the ordinary forms of oscillating engines, in which the steam is admitted to the cylinder through openings in the wearing surfaces of the trunnions and bearings. With that object, the valvular surfaces are formed in vertical planes or discs, at right angles on the trunnions, so as not to be materially affected by

vertical wear. Nevertheless, they are exposed to the inequality of wear peculiar to flat revolving surfaces in contact.

CHAPTER XI.

FOREIGN STATIONARY ENGINES.

FRANCE.—MM. Farcot & Sons, Port Saint-Ouen, exhibited a *direct-acting horizontal condensing steam-engine*, of 60-horse power, arranged to be worked, if need be, without condensation. It has a single cylinder $25\frac{1}{2}$ inches in diameter, 51 inches stroke, with a steam-jacket. Cutting off at 1-15th, and making thirty-six revolutions per minute, with 75 lb. steam, the engine is said to consume only one kilogramme (2·205 lb.) of coal per indicator horse-power per hour. The governor acts in connection with the expansion-gear, in which a double cam is applied to act upon the expansion-blocks or pieces on the back of the slide-valve within the steam-chest. The air-pump and condenser are placed below the sole-plate beyond the cylinder, and the air-pump is worked by a link from a lever moved by the cross-head. The crank-shaft bearing is parted vertically. The fly-wheel is 23 feet in diameter, of which the rim is divided by a central flange into bearings for the two driving-belts employed in driving a portion of the French machinery. The governor of this engine, peculiarly designed, will be noticed in a following chapter upon "Governors."

M. Lecouteux, Paris, exhibited a *horizontal condensing steam-engine*, of 60-horse power, with a $25\frac{1}{2}$ -inch cylinder, 4 feet 9 inches stroke. The condenser and the air-pump are situated under the base-plate, and worked by a lever from the cross-head. The engine made thirty-five revolutions per minute, and worked a portion of the French machinery. The crank-shaft bearing is made with a vertical parting. The pressure is partially removed from the back of the slide-valve by a counter-plate, packed with india-rubber. The steam-ports are only $8\frac{1}{4}$ inches by 2 inches; the exhaust-ports are the same size,—much too small for the free passage of steam, without incurring back-pressure. The same remark applies to the engine of MM. Farcot, in which the steam-port is only $6\frac{3}{4}$ inches by 2 inches, for a $25\frac{1}{2}$ -inch cylinder.

MM. J. F. Cail & Co., Paris, exhibited a *horizontal engine*, with a $14\frac{1}{2}$ -inch cylinder. The bearings of the crank-shaft are placed widely apart, at equal distances from the centre rim of the cylinder, one on each side of the crank, which has two arms, with two overhung fly-wheels, one at each end. Space is thus obtained for the valve-gear excentrics inside the axle-bearing; and, to oppose the leverage of the cylinder, the arms of the crank diverge towards each bearing as an abutment, which is a stronger form than

with the ordinary parallel crank-arms. A separate expansion-valve, in two pieces, on Meyer's system, is applied, variable by hand with a right-and-left screw, and worked by a separate excentric.

MM. Cail & Co. exhibited also a *horizontal air-pumping engine*, generally arranged like the other engine, with an $11\frac{1}{2}$ -inch cylinder, having steam-ports $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch, or only 1-28th of the area of the piston, which is too small a proportion, and must occasion injurious back-pressure. There are, as in the other engine, two fly-wheels, and the air-pump is worked by a continuation of the piston-rod; the pump-valves are worked off the crank-shaft.

MM. Varrall, Elwell, & Poulot, Paris, exhibited a *horizontal steam-engine* with one cylinder. The frame consists of a hollow casting without mouldings, in the style of the modern English tool-framing, neatly formed and finished. A separate variable expansion-valve, on Meyer's system, is applied. The feed-pump is worked direct from the cross-head, and has an air-vessel. The lower guide-bars are cast upon the base, entirely apart from the cylinder, and in doing so it is expected of course that provision for wear is scarcely requisite, where the cross-head slides chiefly upon the upper and adjustable bars, which are bolted to the lower. The frame for the governor is a hollow casting; the governor is parabolic, and is fitted with a central dead weight of 100 lb., movable upon the spindle, as in Porter's governor. The bright work of this engine is, as in English engines, finished chiefly in the lathe. This was the best-looking horizontal engine in the foreign section.

MM. Laurens & Thomas, Paris, exhibited drawings of a *horizontal condensing engine*, in which the entire surface of the cylinders at the sides and ends is covered by steam-jackets. Variable expansion-gear, on Edwards's system, is applied, with a pair of three-ported slides or grids on the back of the valve. The valve is worked in the usual manner, with one excentric; the grids moving with the valve are arrested by an adjustable wedge in the valve-chest between the grids, and the valve moving on, the ports are closed and the steam is cut off for expansive-working. By means of the wedge, or "slide," as it is called, the steam may be cut off at 1-12th or 1-15th of the stroke. The grids are restored to their proper position on the back of the valve for the admission of steam by means of tappets in the valve-chest, one at each end. "The slide," it is considered by the exhibitors, "is particularly adapted for powerful engines, and has been applied on engines of 200-horse power; it works at speeds where a cam [the method of Farcot] could not effectively command the sliding-plates." Engines of this class are said to consume only 17 lb. of steam per indicator horse-power per hour, equivalent, with a good boiler, to about 2 lb. of coal per horse-power per hour.

The fly-wheel is built in two half-widths, the rim being split all round the circumference and the halves riveted together—an elaborate contrivance, apparently to make a more strongly-built wheel. The condenser, of cast iron, is ribbed in the interior, to increase the wet cooling surface, and the water for condensation is introduced, and spread from a conical orifice with an adjustable plug. The air-pump, double-acting, is placed in an oblique position, beneath the bed-plate, and is worked by a lever from the cross-head. Larivière's pneumatic governor is applied, and operates upon the expansion-gear for the regulation of the speed.

M. Quillacq, Anzin, exhibited a pair of *horizontal winding engines*, with 24-inch cylinders, for working coal-mines, which, like Messrs. Thornwill & Warham's engine, are connected direct to the drum-shaft. There are two handles, one to work the valves, the other to work the brake. In this respect Messrs. Thornwill & Warham's engine is better designed, the brake being worked by the foot, leaving only the valves to be worked by hand.

The Prince de Polignac, Paris, exhibited a *steam-engine with a curved cylinder*, the cylinder being a segment of a ring. The piston reciprocated within the cylinder, vibrating upon a central rocking-shaft, with which the two ends of the piston-rod were connected, and from which the motion was transmitted by a lever and connecting-rod to the crank-shaft.

BELGIUM.—M. Scribe, Ghent, exhibited a *double-cylinder horizontal engine* of 30-horse power, on Woolf's system. The cylinders are placed end to end on one base-plate, the larger cylinder, 29 inches in diameter, placed behind the smaller cylinder, 14½ inches in diameter. Two piston-rods from the larger cylinder pass forwards, one on each side of the smaller cylinder, and guided by it, and join the piston-rod from the latter at one cross-head, from which the connecting-rod proceeds to a single crank, with 3 feet 6 inches stroke. The capacities of the cylinders are as 1 to 4, and the steam being admitted to the smaller cylinder for the whole of its stroke, is expanded to five times its original volume; but the expansion is variable. The valves are moved by a single excentric. The pistons thus moving together in the same direction, it follows that the steam from the extreme end of the smaller cylinder is expanded into the extreme end of the larger, through a long passage, whilst the steam from the near end of the smaller cylinder passes to the near end of the larger through a short passage. This arrangement is simple and accessible, but is cumbrous by its length. It is a good type of engine for the service of mills where there is plenty of room. The exhibitor claims the following "unquestionable advantages" for his engine:—40 per cent. less cost as compared with beam-engines, and a saving in foundations, &c.; as it requires less than half the

foundation needed for beam and vertical engines. He states that one of his engines was put down beside a beam Woolf engine of 60-horse power, and that whilst this engine works at the most 50-horsepower continuously, his performs 60-horse power at the same work, with a saving of 18 per cent. in fuel, which he ascribes to the fewness of parts and a reduction of friction.

M. de Landtsheer, Brussels, exhibited drawings of a *horizontal double-cylinder engine*, in which the cylinders are placed side by side, and work upon opposed cranks, so that the steam from the smaller cylinder is exhausted into the same end of the larger, through the shortest practicable passages; in this respect, this engine compares favourably with M. Scribe's, just described.

M. L. Perard, Liège, exhibited a *horizontal blowing engine* with two cylinders, on Fossey's principle, of 200-horse power. The steam-cylinders, non-condensing, are directly connected to the ends of a crank-shaft, with a fly-wheel to regulate the movements; and the two blast-cylinders are placed behind the steam-cylinders, worked by continuations of their respective piston-rods. The engines are fitted with Meyer's variable expansion-gear, having two excentrics, and a cut-off valve in two pieces on the back of the ordinary valve, adjustable on a right-and-left-hand screw. The steam-cylinders are about 19½ inches in diameter, with 27½ inches of stroke, and are regulated to make seventy-two revolutions per minute. The peculiarity of the blast-cylinders consists in the substitution of revolving perforated discs at both ends of the cylinders, for the ordinary clack-valves,—acting, in fact, as slide-valves,—revolved by means of gearing from the fly-wheel shaft. Each cylinder is made with a jacket cast round it, with an interspace into which the air is delivered from the cylinder, and from which it is discharged into the receiver. There are sixteen apertures in each disc, and a corresponding number of apertures in the ends of the cylinder, which are alternately opened and closed by the revolving disc,—opened for the admission of air into the cylinder when the piston recedes, and closed when the piston advances, that the air may be expelled into the jacket, and thence to the main. As there are sixteen apertures in the discs, they revolve one-sixteenth of a turn for each double stroke of the piston, or make one complete revolution for sixteen of the engine. The united areas of the apertures at each end amount to only one-fifth of the area of the blowing piston, for inlet and outlet; whereas, in English engines, the inlet area through flap-valves is preferred to be one-half the area of the piston, and the outlet a fourth. The whiz and labouring of the blast-cylinders, with so limited an area for admission, were very sensible to observers. The revolving discs will no doubt wear loose and leaky; and there is nothing in their design which is likely to supersede the flaps.

PRUSSIA.—The Magdeburg-Hamburg Steam Navigation Company, Magdeburg, exhibited a *non-condensing horizontal engine*, on Corliss's system of variable expansive working—an American invention. The distribution of the steam is worked by means of four cylindrical valves,—two for the admission of steam, and two for the exhaust, one of each at each end of the cylinder, with the shortest practicable steam passages to and from the cylinder. The four valves are worked by a rocking motion from one excentric, which rocks a disc on its centre; from the circumference of the disc, the motion is communicated by four rods carried to and connected with levers on the spindles of the valves. The steam-valves are opened slowly, so as to obviate any shock from the entering steam, with an accelerated motion; but they are quickly closed by means of a "nip cut-off," by which each valve is liberated or detached from the valve-gear, and is closed by a descending weight brought into action. The descent of the weight is controlled by a "dash-pot," a cataract motion, consisting of a vessel containing a plunger which falls freely during the first part of the descent, and is arrested, without shock, upon a cushion of air or of water confined by the plunger itself in the lower part of the vessel, which it is made to fit closely. The exhaust-valves move quickly, and make a large opening for the escape of the steam.

The Sprottau Iron-Foundry, Wilhelmshütte, Liegnitz, exhibited another *non-condensing horizontal engine*, on Corliss's system, similar in all respects to that just described.

Engines like those were first built in the United States; but whilst the nip cut-off and the alternate fast and slow motion of the exhaust-valves is retained, a spring is now used instead of a weight, for more rapidly closing the steam-valves. The object of thus rapidly closing the steam-valves is to gain in efficiency of steam, by reducing or altogether obviating the wire-drawing of the steam, which is incidental, in a greater or less degree, to the action of the ordinary slide-valve. One good feature is to be observed in the large steam-passages, having an area one-tenth of that of the piston—allowed for the free ingress and egress of the steam. But there are weighty objections to the system in its details. A disengaging motion for the valves, which acts in each revolution, is not admissible in modern practice with high-speed engines, and is in any case objectionable. Whilst the weights were employed to move the nip cut-off, the engines could not with ease make more than forty revolutions per minute; the substituted springs have enabled the engines to be moved safely at sixty revolutions per minute. Another great objection is to be found in the irregularity of the cut-off, owing to the want of precision of the valve-gear,—varying occasionally from an admission of steam throughout the stroke, to an admission of nothing at all,—and involving a

very heavy fly-wheel to neutralize those violent fluctuations of force.

M. F. A. Egells, Berlin, exhibited a *beam-engine*, on Woolf's system, of 30-horse power. The beam is carried on a strong central column, ornamented; but the base-plate is a mere plate without depth, bedded on beams of wood,—an inferior arrangement. The valves are worked by means of cams driven from the fly-wheel shaft, with a motion taken off to drive the governor,—a somewhat complex motion. The rim of the fly-wheel is constructed in two thicknesses, breaking joint, and bolted together,—a costly plan. The covers of the plummer-blocks of the crank-shaft bearings are fixed with four bolts; two would be simpler and in better practice.

SAXONY.—M. R. Hartmann, Chemnitz, exhibited a 20-horse power *horizontal condensing steam-engine*, with a 17-inch cylinder, having 38 inches stroke, steam-jacketed. It is fitted with Meyer's expansion-gear, in two blocks working on the back of the valve, adjustable by a right-and-left-hand screw, intended to vary the admission from the whole of the stroke to one-fourth of it. The condenser, air-pump, water-pump, and feed-pump are placed by themselves on a frame at the back of the engine, and are worked from a separate shaft parallel to the engine, driven by mitre-wheels from the crank-shaft.

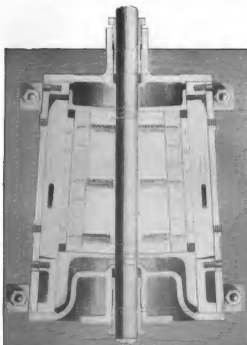
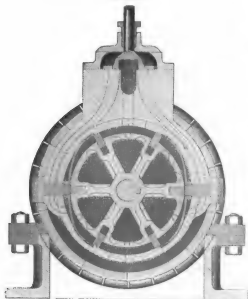
SWEDEN.—M. E. Scheutz, Stockholm, exhibited a *rotary steam-engine*, made by Messrs. Bolinder, in which the "cylinder" and pistons are formed slightly conical—not actually cylindrical, as heretofore—to afford a means of readily taking up longitudinally the wear of the rubbing surfaces. There are six radial sliding diaphragms in the piston, which move in and out twice in each revolution. The friction of sliding radially is reduced by insuring equal pressures of steam on both sides of the diaphragms whilst so sliding. The engine can be made to work expansively. A pressure of about $1\frac{1}{2}$ lb. per square inch is sufficient to keep the engine alone in motion. The mean radius of the body of the piston is 6.6 inches, and that of the cylinder is 7.44 inches; and the useful or working surface—namely, that of the diaphragms—is only $\frac{7}{8}$ inch wide, the length being $8\frac{3}{4}$ inches, giving for two diaphragms a working area of $15\frac{1}{4}$ square inches, with a lineal extent of rubbing surface on the interior of the cylinder of six times $8\frac{3}{4}$ inches, or $52\frac{1}{4}$ inches. An ordinary round piston of the same working area has only 14 lineal inches of circumferential rubbing surface, which is one-third of that of the rotary engine. This engine, tested by the friction-brake, yielded 4.2 horse-power, making 200 revolutions per minute, with a steam-pressure of 35 lb. It is in advance of other rotary engines in the facilities of adjustment for wear; but the



INE



FIGS. 295.



ROTARY STEAM-ENGINE, by M. E. Scheutz, Stockholm.

frictional resistance is likely to be excessive, when compared with that of the ordinary reciprocating engine (figs. 295).

UNITED STATES.—Mr. C. T. Porter, New York, exhibited a *horizontal engine*, known as the "Allen Engine," with variable expansion-gear (Plate XXVIII.). It has an 8-inch cylinder, with 24 inches of stroke, and it made 150 revolutions per minute. It is fitted with Mr. Porter's governor, which regulates the speed by acting on the expansion-valve, and so varying the point of cut-off, instead of the common process of wire-drawing the steam by acting on the throttle-valve. There are two slide-valves at each end of the cylinder,—one of them for admitting and cutting off the steam, and the other for exhausting it. The steam-valves are very simple; they work upon raised facets, and give the entrances for steam into each port,—one entrance in the usual way, by directly uncovering the port, and the other entrance from the other end of the valve, which, overhanging the facet upon which it travels, opens a passage for the steam through a cavity on its under side (fig. 296). It thus

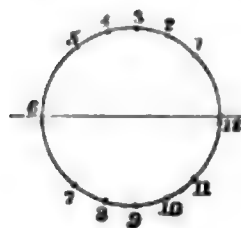
FIG. 296.



answers the purpose of a gridiron-valve; but it is more simple and compact, and it works nearly in equilibrium when opened for steam. The eduction-valves are similar in form, but larger in size. The four valves are worked by a single eccentric fixed on the crank-shaft, with its centre line parallel to that of the crank. The eccentric-strap forms one piece with a "link," more properly a slotted lever, of which the movements are similar to those of the ordinary stationary link, worked by two eccentrics, as used in locomotives. It is, in fact, sustained upon a vibrating rod, pivoted below, and rocks or tips upon the sustaining rod. The horizontal travel of the upper end of the vibrating rod is of course equal to the throw of the eccentric, and is made to time exactly with that of the piston; for this purpose, the very short connection, analogous to what in ordinary engines is called the eccentric-rod, bears the

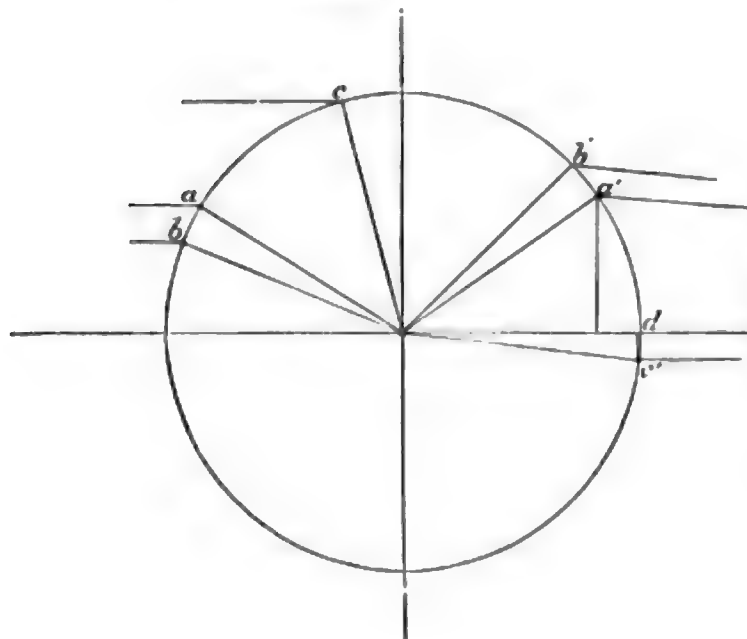
same ratio to the length of the travel that the length of the connecting-rod bears to the stroke of the piston. To equalize the extent and duration of the opening of the ports for steam at both ends of the cylinder, for any degree of expansion, the link is so hung that the arc described by the pin which sustains it is described just below the centre-line of the valve-motion (fig. 297). From this figure, which is intended to represent the successive position of the link, it may be seen that the link plunges very little.

The steam and exhaust-valves are separately worked from this link,—the latter from the upper end of it, with an invariable motion, transmitted through a rocking shaft;—the former from a block, the elevation of which in the link is regulated by the governor, and is varied for various degrees of expansion. The two steam-valves are worked from the same block through separate connections, so that, whilst the motion of the one is being accelerated, that of the other is being retarded. They are worked through rocking levers on a common shaft, the respective motions of which are



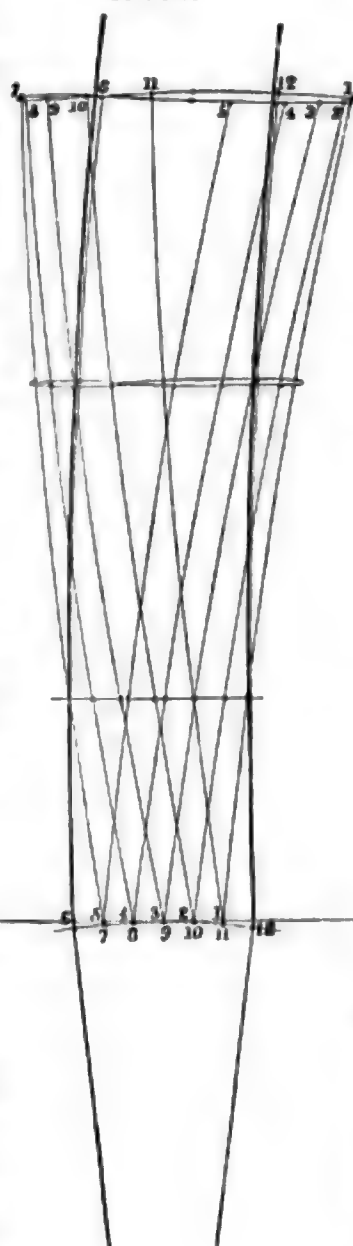
represented by the diagrams (figs. 298, 299), related respectively to the movements for the crank end and the further end of the cylinder. Let a and a' (fig. 298) be positions of the arms of the rocking lever for the crank end, when

FIG. 298.



the crank is on the centre. The port is then open to the extent of the lead, and is further opened, as the crank moves round, by the move-

FIG. 297.



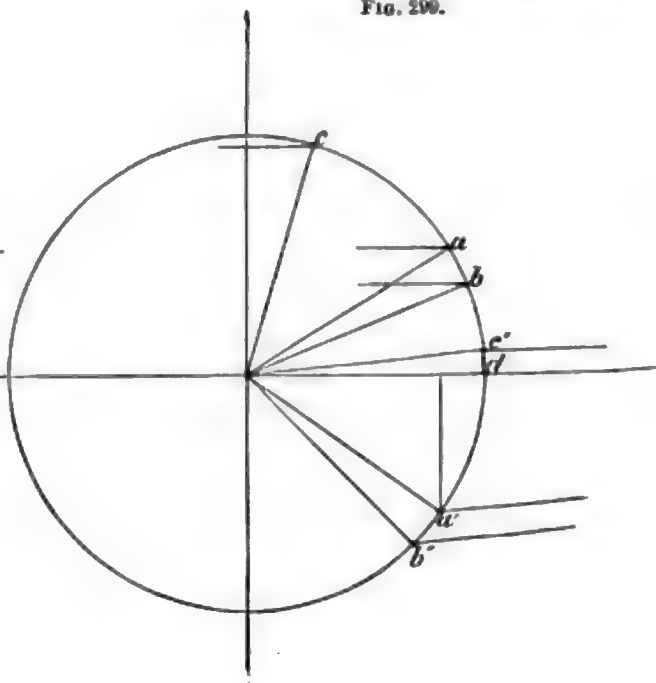
ment of the driving and driven arms of the lever to its extreme positions b, b' . Thence they return to the points c, c' , the other extremes of their vibrations. The annexed indicator-diagrams (fig. 300, page 321) were taken from the engine, two from each end, whilst making from 140 to 150 revolutions per minute. The fluctuating expansion-curves described by the indicator are reduced in the figure to an equivalent regular line drawn by hand. They are excellent examples, and show the good proportions of the valve-gear. Mr. Porter is a strong advocate for high-speed engines, and runs his pistons at from 600 to 750 feet per minute. The engine exhibited was employed in driving cotton and woollen looms.

CHAPTER XII.

STATIONARY STEAM-BOILERS.

The prevailing type of stationary boilers, in England, is the double-flue boiler, consisting of a cylindrical shell, with two flues passing through it from end to end, of which the near ends are fitted up as furnaces; the qualities for the possession of which this type of boiler has been

FIG. 299.



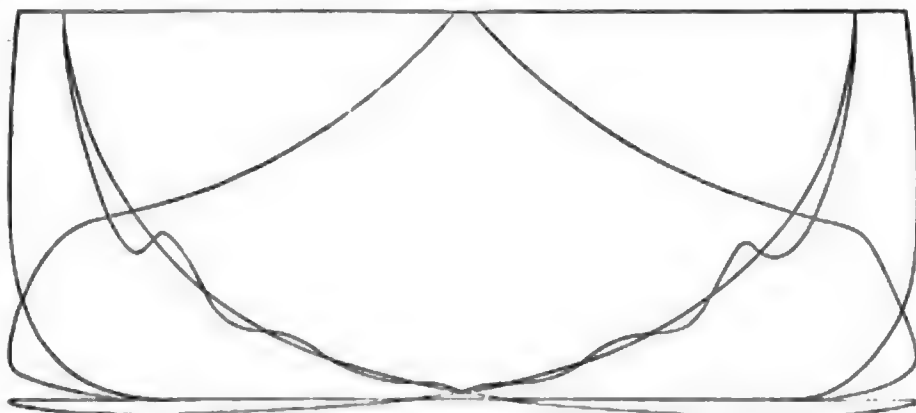
principally adopted, are, in the main, its genuine simplicity, its straightforward construction, and its general efficacy and ability to fulfil the various requirements of practice.

Multitubular boilers, in a variety of forms, are also constructed and used. But they are to be reckoned as special boilers for particular situations, where space is valuable, and compactness an object. They are, probably, also more efficient than the double-flue boiler as evaporators, and economisers of fuel, but they are more expensive; and there is no doubt that the chief quality which recommends them for adoption is their reduced bulk, and the greater simplicity of their installation. Multitubular boilers are either horizontal or upright, so called according to the position of the flue-tubes. The horizontal boilers are either made after the locomotive type, or mixed, having the locomotive flue-tubes, with a common fire-place.

In France, the multitubular boiler is, perhaps, more highly appreciated than in England; but, there, every other consideration is secondary to the prime object of economising fuel, which is costly. As in their steam-engines, so in their boilers, they have given evidence that this is so; and in the removeable fire-box and flue-tubes, they have presented the problem of a compact boiler in a fresh light, from which, probably, English engineers may be glad to take a hint.

Another point in favour of the multitubular boiler is its comparative safety and freedom from violent explosions, as compared with the large double-flue boiler, in virtue of the small diameters of most of the round parts directly exposed to the action of the heat. A steam-boiler fails when the internal pressure of the steam overpowers the strength of the boiler to withstand the pressure. The boiler is said to rupture only, when the failure is not accompanied by a sudden or extraordinary development of elastic force,—the material of the boiler giving way, by cracking or splitting open, and affording an outlet for the contained water and steam. The boiler is said to explode when the failure is accompanied by an extraordinary development of elastic force,—the boiler being rent and torn asunder at strong places and weak places, frequently without distinction. When merely ruptured, a boiler rests in its place; when exploded, it is usually torn from its bed and projected—more or less nearly entire, or in fragments—to considerable distances from its bed, carrying with it or repelling whatever opposes its progress, moving large masses, and affording other evidences of the enormous power suddenly de-

FIG. 300.



INDICATOR DIAGRAMS, from Mr. Porter's Engine.

veloped as a consequence of the failure of the boiler. The essential distinction between the causes of ruptures and those of explosions appears to be indicated by the symptoms, namely, the non-production of extraordinary elastic force in the case of ruptures, and the obvious production of it in the case of explosions. The violence of explosions is to be ascribed to the projectile force acquired by the particles of water and steam within the boiler, by reason of the suddenly developed expansive force of the steam spontaneously generated in the boiler, concurrently with the sudden fall of pressure produced by the sudden escape of steam from the boiler, at the locality of the original failure; or by the sudden enlargement of its volume from any cause, as the collapse of a flue, for example. The particles of water and steam are projected against the shell of the boiler at an enormous velocity, like as many bullets or small shot, making up in velocity what they want in mass or weight; and they communicate their centrifugal momentum to the material of the boiler, necessarily straining it, and, when powerful enough, tearing it asunder, and thus effecting an explosion. Space or latitude is required for the generation of such projectile velocity and the momentum due to the velocity; and if the water were confined within tubes entirely filled by it, there would be no projection of particles, and no explosive momentum, until the level of the water descended below the point of rupture, which explains the fact of the greater safety of water-tube boilers. The action of the projectile force in question is manifested by the bulging outwards of the flue-tubes usually to be observed in exploded locomotive boilers, due to the sudden generation of steam amongst the tubes; and the new theory affords an explanation of the frequent explosions of boilers that occur immediately after the starting of the engine, when, in the first place, the pressure in the boiler is lowered by the sudden admission of steam to the engine, and its rapid consumption by condensation in blowing through condensing engines, succeeded by the immediate spontaneous generation of fresh steam, and a discharge of projectiles within

the boiler. The famous explosion on board the *Great Eastern* steamship may be similarly explained. The feed-water heater consisted of a cylinder surrounding the chimney, forming an annular space filled with water and steam at a high temperature and pressure. The chimney, being unstayed, collapsed like a flue, under the pressure on its outer surface, and thus occasioned a sudden enlargement of volume within the heater, and a simultaneous reduction of pressure; the steam suddenly and spontaneously generated expanded against the collapsed flue and rebounded on the casing, projecting water with it. The moving mass of steam and water thus suddenly arrested expended its momentum on the casing, and rended it asunder.

Explosions are probably in many cases preceded by ruptures. Circumstances determine whether a rupture shall be followed by an explosion. Perhaps the occurrence of an explosion, in ordinary cases, mainly depends upon the locality of the rupture under water, or above water. If under water, water only is expelled, causing very little enlargement of volume, reduction of pressure, or internal commotion, and therefore unlikely to incur explosion. If, on the contrary, the rupture takes place above water, steam issues with the enormous velocity due jointly to its comparative lightness and its tension, 1,800 to 2,000 feet per second, which, of course, would cause the evacuation of the steam-room of an ordinary boiler instantaneously through a very small opening, and therefore an instant fall of pressure, and an instant generation of steam, and the projection of water and steam at the rate of many hundred feet per second within the boiler.

This new theory of the violence of boiler explosions, which may be called the "projectile theory," was first broached by the Author in 1859, and published by him in the *Mechanics' Magazine* for February 10, 1860. It is susceptible of a variety of illustrative, collateral, and confirmatory evidence; and whilst it is compatible with other and partial theories, it serves to account for much that remains otherwise unexplained, with respect to the various forms of the failure of steam-boilers.*

* The *rationale* of the peculiar violence often attending the explosions of boilers formed a subject of frequent discussion between Mr. Z. Colburn, of New York, and the Author, in 1859. We arrived at the conclusion that the spontaneous disengagement of steam from the water in the boiler, after the pressure on the water was more or less relieved by the escape of the steam above the water through a rupture, had something to do in producing the violent disruption, separation, and projection to great distances of portions of the exploded boiler and other heavy masses. Further, the Author suggested, as the form of action, that, the steam being suddenly disengaged throughout the body of the water, the sudden dispersion and projection of the water against the bounding surfaces of the boiler must be the consequence of the efforts of the steam to escape, and that this must be the immediate cause of the violence of its explosive action. The steam, he

Professor Rankine, in an instructive paper "On the Expansive Energy of Heated Water," read at the Institution of Engineers in Scotland in December, 1863, points out that he published, in the *Philosophical Transactions* for 1854, the complete solution of the question of the quantity

argued, must carry the water with it, and by the acquired momentum of the steam and the water, they must be carried like shot through and amongst the bounding surfaces, and would deform and shatter the materials of the boiler in a manner not to be accounted for by simple over-pressure, or even by the simple momentum of steam alone. This explanation was embodied by the Author in the letter published in the *Mechanics' Magazine*, referred to in the text.

Mr. Colburn proposed that he and the Author should jointly prepare and issue a pamphlet on the subject of this new theory of the violence of boiler explosions, to which the Author assented; and, in a note addressed by Mr. Colburn to him, dated November 23, 1859, on the subject of the pamphlet, he expressed a wish that the Author should write a brief introduction, stating the share of each in originating the theory. "I believe," he says, in explanation, "I was the one to suggest the disengagement of steam from hot water. You confirmed my belief in various ways, and you have given me nearly all I knew of the action of steam by momentum."

As Mr. Colburn subsequently expressed a desire to prepare the pamphlet by himself, the Author withdrew from the arrangement for jointly writing it. But it plainly appears that about that time Mr. Colburn made no claim to the projectile theory itself—which he properly ascribed to me—as the *rationale* of the violence of boiler explosions. The Author has thought it right to make this brief statement of the leading circumstances attending the origination of the projectile theory, not so much that he regards the question of priority or "share" in originating the theory as in itself of any great moment, but chiefly that he may set himself right with the public on a point of veracity,—Mr. Colburn having more recently laid claim to the initiation of the idea of percussive action, and having referred to his own contributions to the *Engineer* on the subject, as evidence of his priority of claim, by reason of prior publicity. But it is to be observed, in the first place, that it was understood between him and the Author, that, pending the preparation of the proposed joint pamphlet, he should air the subject in the columns of the *Engineer*, and mature it for discussion in the pamphlet,—he, he it remembered, to write the body of the pamphlet, the Author to write only the introduction, as aforesaid. When, therefore, he broke up the arrangement for a joint authorship of the pamphlet, monopolizing it, with the publicity attending it, for himself, and then pointed to interim articles in the *Engineer* as evidence of prior publicity, and therefore of a prior claim to originality, one is apt to imagine that a breach of good faith was committed.

Under the circumstances,—subsequently to the termination of the arrangement for jointly writing the pamphlet, but prior to the publication of it by Mr. Colburn,—the Author published his letter on boiler explosions in the *Mechanics' Magazine* of the 10th February, 1860, in order to forestal any further possible attempts to monopolize the merit of the origination of the projectile theory; and so little did Mr. Colburn before that time recognize the essence of the theory, that, in airing the subject in the *Engineer* of November 4, 1859, he altogether ignored the water in the boiler as a projectile. "To believe that the steam [disengaged from the water] would act by percussion," says he, "in a manner resembling the action of non-elastic bodies projected into contact [!], is all that is necessary to understand the process of a boiler explosion." And

of mechanical energy which a given weight of water, heated to a given temperature, is capable of exerting in the act of partially evaporating, without receiving heat, until it falls to a given lower temperature. He gives the annexed table, showing, in the first column, the temperature of the water; in the second column, the expansive energy of one pound of water; in the third column, the velocity which that energy would impress on a projectile of the weight of the water itself, one pound; in the fourth column, the final volume of expansion of the water and steam in cubic feet per pound; in the fifth, the absolute pressure in pounds per square inch.

Initial Temperature.	Energy.	Velocity.	Final Expansion.	Initial Absolute Pressure.
Fahrenheit.	Foot pounds.	Feet per Second.	Cubic Feet.	Pounds per Square Inch.
212°	0	0	0·00	14·70
248	726	214	0·95	28·83
284	2,779	423	1·87	52·52
320	6,052	624	2·73	89·86
356	10,422	819	3·56	145·8
392	15,826	1,010	4·36	225·9
428	22,156	1,194	5·11	336·3
.....				
about	about	about	.....	.....
2,360	912,500	7,666	26·36	unknown

UNITED KINGDOM.—The boilers employed to supply steam for the service of the Western Annex, were constructed by Messrs. Benjamin Hick & Son, Bolton, an old and celebrated firm. They were six in number, 30 feet long, 6½ feet in diameter, with two flues 2 feet 6 inches in diameter. The shells were of $\frac{7}{16}$ inch best Staffordshire plate, and the ends $\frac{3}{8}$ inch thick. The flues were all $\frac{3}{8}$ inch thick, of best double-worked

further on he remarks,—“that steam suddenly discharged acquires momentum like any solid body, and that it is this momentum, discharged by suddenly disengaged steam, that produces the more destructive consequences by which boiler explosions are so often accompanied.”

In the second place, that Mr. Colburn did after all first suggest the *disengagement* of steam from the water is not strictly correct. What he really first suggested was that all, or nearly all, the heated water, when relieved of the superincumbent pressure, was flashed into steam (see the *Engineer*, September 23, 1859); and for this idea, however absurd, he was indebted to Mr. Jacob Harshman, of Dayton, U.S., whose views on explosions had been published in the *Engineer* a few weeks previously. But even if he had suggested the spontaneous disengagement of steam from the water, in the case of the rupture of a boiler, he had long before been anticipated by others, of which there is the sort of evidence which alone he appears to recognize, namely, publication. (For additional discussion on this matter, see the *Mechanics' Magazine* for May 3 and 10, 1861; and for September, October, and November, 1863.)

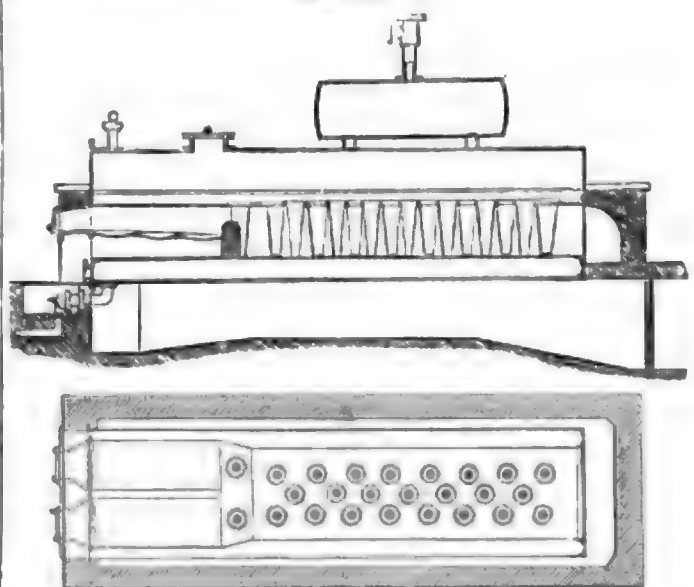
Staffordshire plates, except at the furnaces, which were made of Bowling plates. The longitudinal joints of the flues were welded, and their cross joints were made flush, and covered with T iron circular ribs to strengthen them, on the principle originally and perseveringly advocated by Mr. Wm. Fairbairn. The circular ribs are now generally recognised as a sound and most effective application for stiffening flues subject to collapsing steam, and they are one of the best things, if not actually the best thing that has been done for cylindrical boilers since the application of double internal flues. Mr. Fairbairn found that the power of resistance of a plain tube to external pressure varies inversely as the unsupported length of the tube, inversely as the diameter, and inversely as the square of the thickness.

Supplementary to these boilers, three additional boilers were supplied and erected by Mr. Henry Cater, on his system. They are described in the subjoined notice.

Mr. Henry Cater, London, exhibited a model of his *multitubular boiler*, consisting of a cylindrical shell, containing two strata of flue-tubes, to conduct the products of combustion from the back of the furnace and flue under the boiler, to the front, into a small box, and again to the back of the boiler, and thence to the chimney. Thus the lower half of the shell is entirely exposed to the direct heat of the furnace. This boiler occupies about half the space, and requires about two-thirds of the quantity of brick-work needed for an ordinary double-flue boiler of equal power. It is an efficient and practical boiler.

Messrs. W. & J. Galloway, Manchester, exhibited a model of the *Galloway boiler*, well known by their name, which is made with two

FIG. 301.



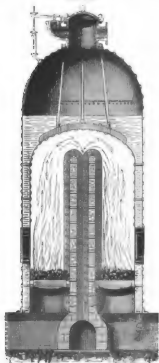
THE GALLOWAY BOILER, with vertical water-“tubes,” by Messrs. W. & J. Galloway, Manchester.

internal furnaces joined to a large oval flue within the boiler; in the oval flue there are a

number of vertical conical water-passages, uniting the top and the bottom, so that a free circulation of water is maintained, and a free delivery of steam, whilst a considerable addition to the heating surface is effected. It is a species of "water-tube" boiler; and the vertical passages being placed in the thoroughfare of the draft, they promote also the mixture and combustion of the gases, making a generally good and efficient boiler (fig. 301).

Messrs. Thomas Dunn & Co., Manchester, exhibited an *upright boiler*, on an effective principle,—that of partly detaining the products of combustion, and reversing the draft downwards. The boiler is cylindrical, with a domed fire-box within, divided transversely by the water-partitions. There are two grates—one on the outer side of each partition—and the currents ascending from them meet at the crown, are deflected, and descend through the central flue formed by the two partitions (fig. 302). Another

FIG. 302.

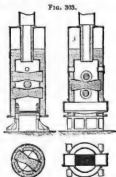


UPRIGHT BOILER, with down-draught; by Messrs. Thomas Dunn & Co., Manchester.

boiler, a modification of this, is constructed with but one vertical diaphragm, near one side of the fire-box, and a single fire-grate.

Mr. Robert Armstrong, North Woolwich, exhibited *Armstrong & Bowman's upright boiler*, which contains within a cylindrical shell a number of transverse

double-cone "steam-generators," crossing an internal upright flue or fire-box, similarly to Messrs. Galloway's arrangement for the horizontal flue. The transverse tubes, within which the water circulates to a certain extent, baffle and divert the ascending hot currents. The ends of the "generators" project into the surrounding water-space of the boiler, and so throw off the steam which is discharged from them out of contact with the vertical sides of the fire-box (fig. 303).



ARMSTRONG & BOWMAN'S UPRIGHT BOILER, with transverse double-cone steam-generators; by Mr. Robert Armstrong, North Woolwich.

Mr. E. T. Wright, Walsall, exhibited a model of his *diagonal-steam boiler*, in which the plates are bent diagonally, and the seams are joined and riveted diagonally, so as not to present any longitudinal seams, with the design of equalizing the strength of the boiler, and increasing its power of resistance to bursting strains.

Mr. Joseph Harrison, London, exhibited a novel and ingenious *cast-iron boiler*, composed of a series of cast-iron hollow globes, about seven inches in diameter, formed with two or three faced openings, for the purpose of uniting them into one system, with free communication between them. They are built up in parallel rows, and are united by means of long bolts which pass through each row from end to end, and are screwed taut outside. Transversely, likewise, the parts are united and secured by through bolts, so as to form one system securely held together. Built into a furnace, the fire acts directly on the lower stages of the boiler, in which the water is contained, and the steam ascends into the upper parts; and it is obvious that, according to the extent of exposure to the heat, the steam may easily be superheated. This plan of boiler is liable to the objection of a deficiency of water-room; but it is certainly a safety boiler, inasmuch as, should any part fail by over-pressure, the chances of danger, in consequence of their smallness of diameter, are greatly less than when an ordinary boiler explodes.

FRANCE.—In the construction of multitubular boilers, the French engineers, M. Chevalier and M. Durenne, proposed that the fire-box and the tubes should be so constructed as to be readily removable from the shell, for purposes of clean-

ing and repair; and thus to extend their usefulness and efficiency in admitting of the use of impure or sedimentary water, with ready means of removing the deposits. This is a novelty in boiler-making.

MM. Laurens & Thomas, Paris, exhibited a 30-horse-power *multitubular boiler*, with removable fire-box and flue-tubes. These engineers appear to have been the first to apply and work out the removable system. The boiler is constructed with a central fire-tube, and a number of small flue-tubes, both of which—the fire-tubes and the flue-tubes—are fixed at one end to the front plate of the boiler; and at the other end to the outer plate of a smoke-box or chamber. The whole system, thus united, is fixed into its place within the boiler by a single joint with bolts and nuts at the front; and may be entirely withdrawn for inspection in the same way. By this arrangement, also, the parts exposed to the action of the fire may freely expand and contract, independently of the outer shell. The

smoke from the return flues is collected in the uptake, and delivered to the chimney at the front. Two or more systems of fire-tubes and return flues may be fixed into one shell. India-rubber packing for the joint answers very well. The system of removable fire-boxes facilitates their being renewed, with duplicate fire-boxes in store. Upwards of 200 boilers, with removable fire-boxes in successful operation, have been constructed by the exhibitors. The system has also been applied to supplement the elephant boiler, in common use in France,—a species of boiler consisting of three longitudinal cylinders, two of them in the lower part of the furnace, and the third and largest above them, and united to them by tubes. The end of the upper cylinder being cut off, the removable furnace is introduced and fixed in place. In some cases, two furnaces are introduced, one at each end. The removable furnace is specially adapted for agricultural engines, which are worked with all sorts of impure water (fig. 304).

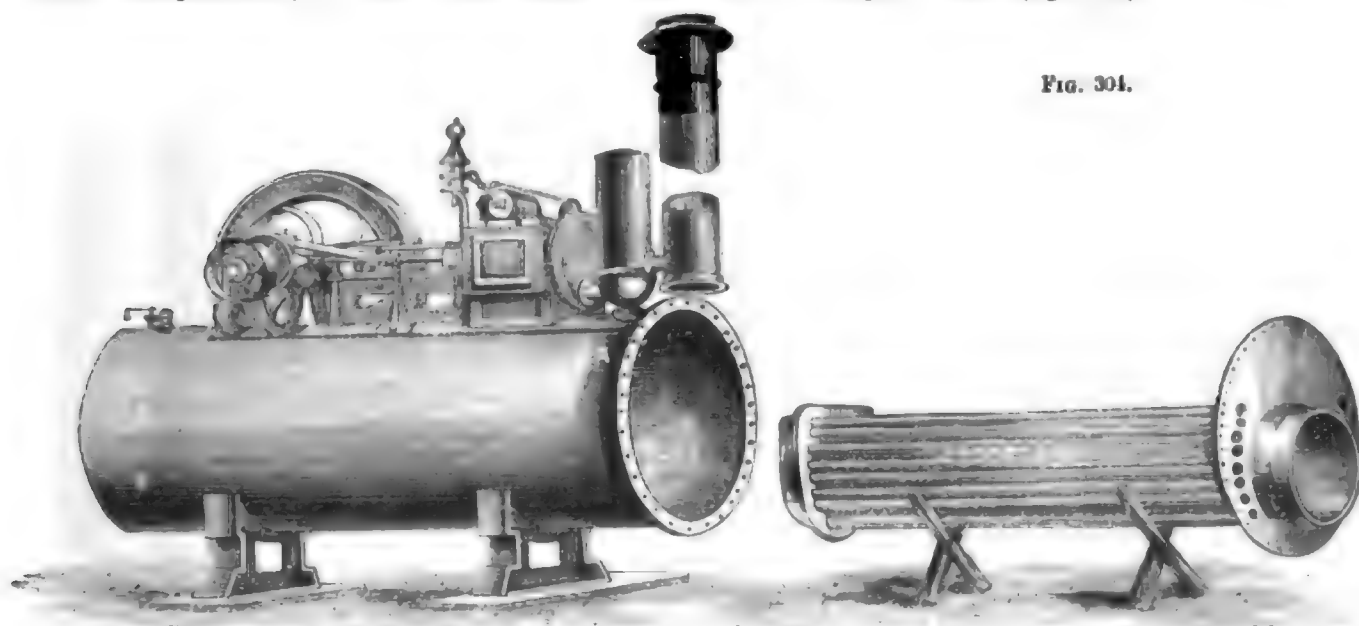


FIG. 304.

30-HORSE-POWER MULTITUBULAR BOILER, with removable fire-box and flue-tubes; by MM. Laurens & Thomas, Paris.

MM. Farcot & Sons, Port Saint-Ouen, exhibited a 30-horse-power boiler, with movable fire-box and multitubular flues, arranged in a direct line through the cylindrical shell of the boiler, and fixed into the front and back plates. To remove the furnace and flues, both of these plates are required to be unfastened and removed. This system, of more recent origin than that of MM. Laurens & Thomas, is an imitation of it, which is, in some respects, inferior to the original, as there are two joints to make and unmake, and there is no freedom for independent expansion and contraction; moreover, it is not, with its direct draft, so well adapted for consuming the smoke from coal as the other furnace, with the return draft, in the smoke-box of which an opportunity is offered for mixing the gases and the air, and so promoting combustion, before entering the multitubular flue. On the contrary, the strength of the

direct draft is less affected or reduced by the multitubular flues than that of the reversed draft; whilst MM. Farcot maintain that with the direct flues they obtain a greater sectional area of flue way.

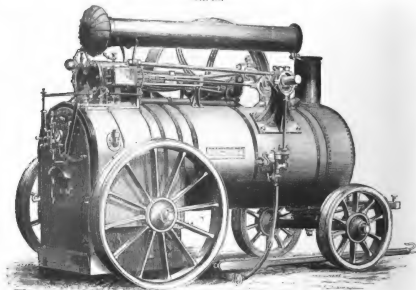
M. Zambaux, St. Denis, exhibited an *upright multitubular boiler*, having 216 tubes, $2\frac{1}{4}$ inches diameter, with only $\frac{5}{16}$ inch clear space between the tubes. The clearance is too small, and must render the boiler inefficient for practical use.

ITALY.—M. F. Grimaldi exhibited a *rotary steam boiler*, consisting of a cylindrical shell, with multitubular flues through it, revolving on trunnions. It is, for nearly the whole length, inclosed in the furnace, and exposed to the action of the flame above as well as below. The following notice of the boiler occurs in the Italian Catalogue:—"The entire boiler being an evaporating surface, and being able to contain

twice the quantity of flues, the weight of the whole may be reduced to a fifth, and the expense of the first manufacture is not more than two-thirds for boilers of more than 15 horse-power. Moreover, as it is a physical fact that the agitation of a liquid renders it more easy of penetration by heat, it follows that, with a given heating surface, this boiler will convert the water into steam more readily than any other. The inventor asserts that by the rapidity of vaporization, the superheating of the steam, and the small volume of the boilers, there is a

saving in coal of 30 per cent. The boiler is constructed for the highest pressure: its incessant revolutions prevent its being injured by the heat, whatever may be the level of water in the inside. It is easy to take to pieces for inspection, inasmuch as it is not built into the masonry. The inventor proves that it is impossible for the boiler to become incrustated or to corrode, especially in marine engines, where the opening for the passage of the steam is protected by several rows of tubes, which, converting it into steam, stop the water thrown against them."

FIG. 365.



20-HORSE-POWER PORTABLE DOUBLE-CYLINDER ENGINE, by Messrs. Ransomes & Sims, Ipswich.

CHAPTER XIII.

PORTABLE ENGINES.

The demand for and the use of portable engines—or engines with their boilers on wheels—has arisen nearly altogether since 1851. They are of special utility for supplying steam-power out of doors,—in the field, for agricultural and other operations, and in the yard for all purposes where horse-power has been employed. Portable engines are usually constructed with locomotive-boilers, having flush tops, that is to say, with the top of the fire-box flush with the top of the barrel. The tubes are from 2 to 2½ inches in diameter inside, and from 5 to 7 feet long. Directly upon the top of the fire-box a horizontal high-pressure steam-engine is fixed, as well as all the other parts of the engine, thus

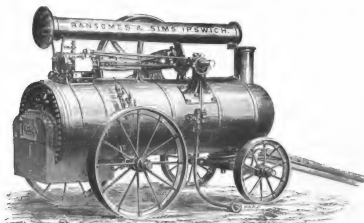
superseding the earlier practice of placing the engine on a bed-plate bolted to the boiler. Instead of the over-neck crank formerly used in portable engines, a cranked shaft is generally adopted,—a construction that admits of the power being taken off from either end of the shaft, which generally carries a fly-wheel on one end and a pulley on the other.

Messrs. Ransomes & Sims, Ipswich, exhibited a number of engines of various sizes. Compared with the engines of most other makers, their steam-cylinders are smaller, but the boiler is quite as large. Unlike many other makers, they prefer to place the engine in the centre line of the boiler; and, to save height, the exhaust-pipe, which passes outside along the top of the boiler, is flattened where it passes under the crank-shaft to clear the end of the connecting-rod. These engines have been designed with care, which has

been extended to the smallest details. There is plenty of space between the flue-tubes, and they are arranged as much as possible in vertical parallel rows. The governor-gear consists of one single lever fixed on the throttle-valve spindle, gearing directly into the sleeve on the governor-spindle. The feed-pumps are neatly constructed, and are placed directly under the shaft, slightly below the centre line of the barrel of the boiler; the feed-cock, in one piece with

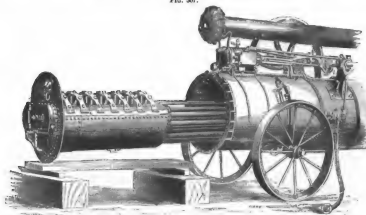
the pump, admits water into the boiler, or allows it to flow partly or wholly back into the water-tub as required. The slide-excentric can be easily adjusted and reversed. The brackets carrying the bearings of the crank-shaft are stayed by rods to the cylinder, and might be advantageously dispensed with by making the brackets somewhat stronger. A small counter-weight is cast on the rim of the fly-wheel, for balancing the crank and the end of the connect-

FIG. 308.



10-HORSE-POWER PORTABLE ENGINE, with Biddell & Ball's Boiler, by Messrs. Ransomes & Sims.

FIG. 307.



BIDDELL & BALL'S BOILER, showing the tubes partly withdrawn.

ing-rod. The locking-gear of the fore-carriage is simple and efficient,—on the ball-and-socket principle. The boilers are not felted, but only wood-lagged, and cased with sheet-iron. Besides

the ordinary boiler of the locomotive type, these makers also exhibited engines constructed with Biddell & Ball's boiler, a novel construction of cylindrical tubular boiler, of which the front,

together with the tubes, tube-plates, and fire-box, can be entirely separated and removed from the barrel for being cleaned and repaired by only unscrewing a few bolts. In localities where the only water to be had is dirty, muddy, or calcareous, this sort of boiler possesses material advantages (figs. 305, 306, 307).

Messrs. Tuxford & Son, Boston, understood to be the first firm that engaged in the business of constructing portable engines, exhibited three kinds of engines. The first is a *housed engine*, of 10-horse power, with two upright cylinders and a crank-shaft over head, altogether a very well-designed engine. The boiler in this as well as the next class of engine is made with return flue-tubes, the flue leading from the fire-box to the uptake being parted in the middle by a water-space. These boilers are probably more economical than the common ones, and do not suffer so much from leaky tubes as the latter, in which currents of cold air may happen to rush right up to the tubes through uncovered fire-bars. The safety-valve, loaded in the usual manner with a spring-balance, is placed on the man-hole cover—thus saving an extra hole in the boiler. There is a damper in the chimney,—a useful appendage to the engine,—wanting in the other engines exhibited. There is a disadvantage in the distribution of the weight of the housed engine,—that the whole weight of the engine proper, with its house, and at least a third of

The peculiar construction of boiler adopted necessitates a barrel of great diameter, but of no great length. With the return-tubes, this boiler gets up steam as quickly as any boiler of the usual type, and it works with an economy in the consumption of fuel. The plan followed by Messrs. Tuxford & Sons, and by most other makers, of carrying the exhaust-steam pipe through the steam-space of the boiler, though it cools the fresh steam within the boiler, is more slightly than the plan of the external pipe. The feed-pump is driven directly from off one of the stepples. The engine is placed in a box attached to the end of the boiler, and is thus protected from dust and rain—a material point; for where the engineman in charge can, without much extra trouble, keep his engine clean and bright, he is likely to take more interest in keeping it in good order.

The engine is very compactly arranged. The boiler is covered with a double layer of felt. The starting-valves are formed of sector-discs, which do not wear quite so equally as others in common use.

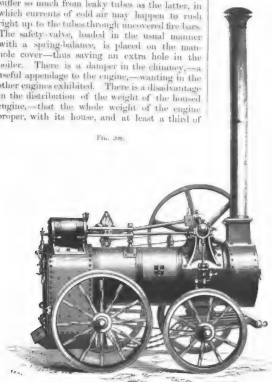
The next is the *housed engine*, with inverted cylinder, of 8 horse-power. It is fitted with an expansion-slide, and the cylinder is steam-jacketed. The feed can be regulated very conveniently from the outside of the engine-house. The feed-pump can, by means of a three-way cock, be always kept working with water in the barrel, pumping water into the boiler or returning it to the suction. The piston-rod guide-blocks are made with adjustable linings. The steam-jackets are supplied directly from the boiler. The expansion-slide eccentrics can be set for any degree of cutting off with little trouble.

The third is an ordinary portable engine.

Messrs. Ruston, Procter, & Co., Lincoln, exhibited several portable engines of different sizes, all of the ordinary construction. The working parts are strong and well proportioned; the cylinders are said to be rather larger than in other engines of the same

power. The weight of the boiler, are laid upon the front wheels; moreover, the steeple arrangement causes the whole machine to stand a couple of feet higher than the common portable engines with horizontal cylinders and locomotive-boilers.

The crank-shaft bearings are adjustable sideways in one direction, but not in the other, by means of set-screws, to allow, probably, for wear of brasses in the direction in which the power is generally taken off. A lock-up safety-



PORTABLE ENGINE, by Messrs. Ruston, Procter, & Co., Lincoln.

counterbalanced. The boiler is not very strongly stayed; the front of the fire-box has only four $\frac{3}{4}$ -inch screwed stays, and two $\frac{1}{2}$ -inch through stay-bolts. The fire-hole doorway is made with a deep wrought-iron ring riveted between the inner and outer plates with long rivets; but a joint made with a thin ring and short rivets is more likely to remain steam-tight. The fire-box is without mudholes. One novelty worth imitating was the foot-plate for more conveniently getting at and lubricating the engine.

Messrs. Robey & Co., Lincoln, exhibited an 8-horse-power engine. The crank-shaft bear-

ings are fitted with set-screws for adjustment laterally; but there are no check-nuts on the keys of the connecting-rods. The boiler is constructed with a water-space around and below the grate, for the collection of sediment; but it is inconvenient in preventing easy inspection and access for repair of the inside of the fire-box.

Messrs. Garrett & Son, Leiston, exhibited portable engines of different sizes, in which the makers aim at simplicity in details and good finish. Besides the common safety-valve, loaded by a spring lever-balance, there is another, loaded directly by a spiral spring. A counterweight is cast on the fly-wheel. The cylinder and valve-chest are cast in one piece, thus saving a joint, but entailing more labour in getting up the slide-face. The feed-pump has two delivery valves, to ensure efficiency of working.

Messrs. Hornsby & Sons, Grantham, exhibited several engines, which bore evidence of great care in the general design and in the construction of details. The boilers, having a raised fire-box, have a steam-chest on the top of the fire-box, in which the cylinder is enclosed, and to which it is fixed, the ends of it being outside the steam-chest. The flat surfaces of the boilers are regularly and effectively stayed, and the tubes are well arranged, being everywhere $1\frac{1}{4}$ inch apart. The chimney is fitted with a spark-arrester, consisting of a wire-gauze net. There are holes in the firebox and the shield plate, to admit air above the fuel, for the purpose of preventing smoke to some extent. The hind-wheels

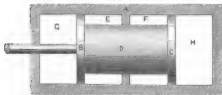


6-HORSE-POWER PORTABLE ENGINE, with Mr. E. E. Allen's Double Single-trunk Cylinders; by Messrs. Hornsby & Sons, Grantham.

are supported on springs,—a useful adjunct to a portable engine, often exposed to travelling over rough roads. The crosshead is guided at top and bottom by round bars, and fitted with adjustable brass liners, having lubricators cast on: these guide-bars are at one end screwed into the cylinder-cover, and the outer ends are fixed to a bracket. The safety-valve is placed on the top of the steam-chest, and serves as a support for the chimney when laid down. The surplus feed-water is returned through part of the exhaust-pipe to the suction. The crank-shaft brackets are neat, and the brasses are adjustable laterally by means of screwed keys. The crank-shaft is balanced by a counterweight on one of the fly-wheel arms. The slide-valve eccentric can be easily adjusted or reversed. The hind axle passes through the middle of the fire-box (fig. 309, page 329).

An entirely new arrangement of double expansive portable engine has been patented by Mr. Edward E. Allen, of London, and constructed by Messrs. Hornsby & Sons, of Grantham (fig. 310). This engine was not exhibited, except by way of a model; but it is worthy of further notice. "The cylinder (fig. 311) is

FIG. 311.



ALLEN'S DOUBLE SINGLE-TRUNK CYLINDER. (Diagram to illustrate its action.)

made double the ordinary length or stroke of the engine, and has a division (A) in its centre. The ordinary piston is, as it were, divided into two parts (B and C), but united by a trunk (D), which passes through the division (A). Steam is admitted alternately into the annular spaces (E, F), and at the termination of stroke passes respectively to the ends of the cylinder (G and H), where it is fully expanded. The steam from

FIG. 312.



INDICATOR-DIAGRAM, FROM ALLEN'S DOUBLE SINGLE-TRUNK CYLINDERS. (Diameter of cylinder, 14 inches; diameter of trunk, 2½ inches; stroke, 12 inches; ratio of annular space to cylinder and passages, 1:5½; speed, 125 turns per minute; steam pressure in boiler, 65 lb. per square inch.)

the boiler acting only on small portions of the piston, produces no injurious shock, the whole surface of the pistons being acted upon by the partially expanded steam only." Indicator-cards, taken from one of these engines (fig. 312), show that the size of the trunk may be readily made so as to give any amount of expansion desired.

Messrs. Brown & May, Devizes, exhibited two strong and well-made engines; but the corners of the fire-box are made with the old-fashioned angle-irons,—a plan inferior to the usual method of flanging the plates. The fire-box is not covered. The crosshead has packed stuffing-boxes and screwed glands for sliding on the round guide-bars. A counterweight for balancing the crank is applied near the boss of the fly-wheel. The cylinder is steam-jacketed and clothed, which is economical, even for as low a degree of exhaustion as in cutting off at five-eighths of the stroke.

Messrs. Clayton, Shuttleworth, & Co., Lincoln, exhibited several engines. In their patented engines the cylinder is steam-jacketed, and inclosed in the smoke-box, while the rest of the engine proper is arranged on the top of the boiler in the usual way. The boiler is made with a flush fire-box, strongly and equally stayed; the tubes are arranged in diagonal rows, and are placed well apart. There are mud-holes wherever required, and the water-plug is placed on the manhole cover, thus saving a hole in the shell of the boiler. The fire-door hole is made with a thick wrought-iron ring riveted between the inner and outer plates,—a plan which has already been alluded to. The boiler is fitted with a neat lock-up safety-valve, loaded directly with a spiral spring,—a useful safety adjunct. The parts which apply to the barrel or round part of the fire-box are planed to the form on a radial bar-planing machine, and they require hardly any extra fitting, every detail being made according to standard templates. The crank-shaft brackets are cast hollow; the bearings have three brasses—a bottom and two side ones, each of which is adjustable; the bottom one by means of a screwed key, and the side brasses by set-screws. The bearings of the 8-horse portable engine are 3 inches in diameter and 5¼ inches long. These are good proportions; for long bearings are beneficial, particularly in quick-going engines. The castings are well finished. The slide-valve guide-rod is simple: it is simply a gland-shaped flange fixed on the stud-bolts of the slide-rod gland, which are for this purpose made about 6 inches long. The guide-blocks have adjustable cast-iron linings on the wearing side. These engines are complete and well designed.

Messrs. Barrett, Exall, & Andrewes, Reading, exhibited several excellent portable engines. The fire-box is well stayed; but, nevertheless, the stay-bolts are put

in with countersunk heads, which, though the appearance may be improved, can scarcely be expected to add to the strength of the boiler. The fire-door hole is made with a stout ring. The cylinders are steam-jacketed, and are worked with separate expansion-valves for engines of 8 horse-power and upwards. The crank-shaft is not counterweighted.

Foreign Portable Engines.—None of these was remarkable either for workmanship or for design.

MM. Cail, Halot, & Co., Brussels, exhibited a small portable engine, similar to the portable engines built in England fifteen years ago. The engine rests on a bed-plate fixed to the top of the boiler. The feed-pump is driven directly from the crosshead,—a practice long ago done away with in England. The fire-box is cylindrical, and of a diameter larger than that of the barrel. The tubes, eighteen in number, and 2½ inches inside diameter, are arranged in two parallel rows. The engine is fitted with variable-expansion gear. The governor-gear is circuitous and complicated.

The Cologne Engine Building Company exhibited a portable engine, in which the tubes were in zigzag rows, and very near to each other. The engine rested on two heavy cast-iron frames fixed to the boiler. This engine probably weighed half as much again as an English portable engine of the same power.

M. De Coster, Paris, exhibited a portable engine with a very heavy saddle bed-plate. The fire-door is very low down in the fire-box, and the flue-tubes are in zigzag rows, and very close together. The steam-pipe is large and exposed; there is variable expansion-gear, and a very heavy fly-wheel. The engine was not sightly.

M. Durenne, Paris, exhibited an engine in which two shafts are employed, with a crank on the end of each; the cranks, facing each other, are joined by the crank-pin. This construction is used in preference to one bent crank-shaft, as generally used. The cylinder is enclosed in a square chest on the top of the fire-box, surmounted by a high dome. The other parts of the engine rest on a bed-plate, with which the plummer-blocks are cast in one piece. Instead of with the ordinary spring balance, the valves are loaded with a common lever and weight. A small heavy pulley is fixed on each end of the crank-shaft, acting as a fly-wheel.

MM. Cail & Co., Paris, exhibited an engine similar to that of MM. Cail, Halot, & Co., having in addition a feed-water heater under the barrel of the boiler. The tubes are large, and pitched closely in diagonal rows. The crank-shaft brackets are cast in a piece with the sole-plate or saddle-plate on the boiler.

Semi-portable Engines.—Messrs. Appleby Brothers, London, exhibited two semi-portable engines, in one of which the boiler, of the locomotive form, is placed on a hollow bed-plate, and

the engine is placed under the boiler, and fixed to the bed-plate, with its cylinder in the lower part of the smoke-box. It is a handy arrangement. The engine was employed to work the Swiss ribbon-loom. The other portable engine has an upright boiler on wheels, with crank-shaft overhead.

Messrs. T. M. Tennant & Co., Edinburgh, exhibited a well-proportioned 8-horse-power engine on an upright boiler, with the cylinder overhead, and the crank-shaft below, with an overneck crank. The boiler is fixed on a cast-iron frame with a square flange. The connecting-rod is forked, and one eccentric is applied to work both the slide-valve and the feed-pump (figs. 313).

Messrs. Hornsby & Sons, Grantham, exhibited a 10-horse-power horizontal engine, with steam-jacket and variable-expansion valve, adjustable by a double-screw. It is similar in appearance to their portable engines.

Messrs. Ransomes & Sims, Ipswich, exhibited a simple, strong, and well-designed engine, with expansion-valve.

Mr. F. H. Wenham, London, exhibited a "thermo-expansive steam-engine," which has already been noticed (see *ante*, page 314).

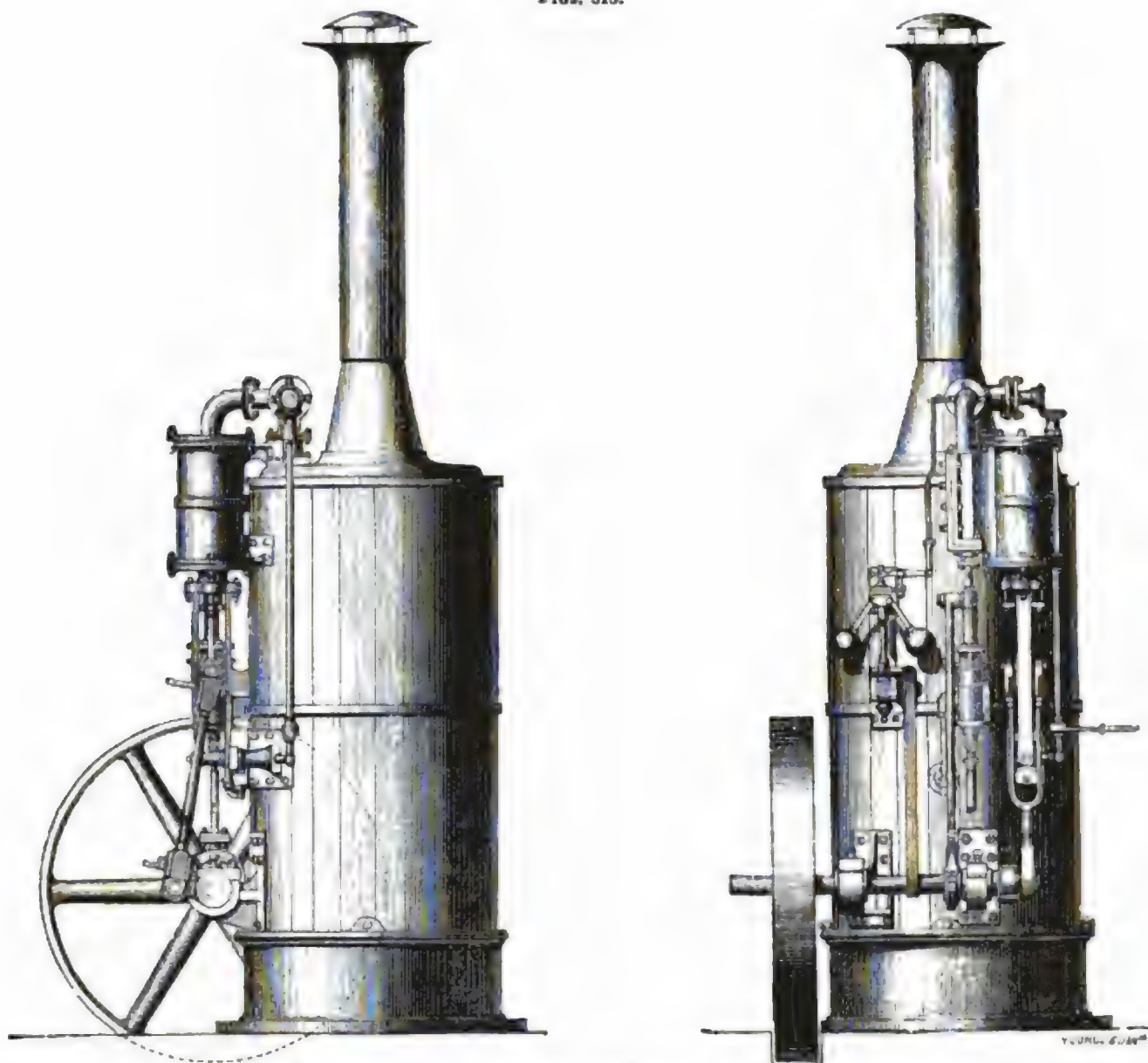
MM. Laurens & Thomas, Paris, exhibited an engine placed upon cast-iron base-plates at the fire-box and the smoke-box ends. The boiler, horizontal, with return-tubes, is so constructed that the whole interior, with tubes and tube-plates, can be drawn out for cleansing and repair. The boiler is three feet longer than the system of tubes, containing a body of water the purpose of which is to ensure a steady water-level; but more time is required to get steam up than if the additional water-space were absent. The feed-water is passed through the exhaust steam in a large vessel placed on the top of the boiler, but in such a way as to prevent access to the piston without removing the vessel. There are very heavy crank-shaft brackets and fly-wheel. A compressed-air governor is used, of a kind much in use on the Continent. The engine rests on a bed-plate, and is generally well arranged; but it has a large feed-pump driven from the crosshead. The peculiar form of boiler has already been noticed at page 325.

CHAPTER XIV.

TRACTION-ENGINES.

Traction-engines were originally devised to supersede horse-power on common roads, previously to the general adoption of railways for purposes of transport. The railways set them aside for a time, as they in a great measure set aside horse-power. But within the last few years traction engines have been revived, and

FIGS. 313.



SEMI-PORTABLE ENGINE, by Messrs. T. M. Tennant & Co, Edinburgh.

have been very much improved in design and construction, and better adapted for the work to be done. It has been established that, on the best ordinary roads, the heaviest loads can be drawn with greater economy than by horse-power; and that, in ascending or descending the steepest hills, or in passing over soft and marshy ground, where no roads exist, traction-engines have taken loads which could not have been transported by any available amount of horse-power. As a feeder to the goods-traffic of railways, by superseding the necessity of short and expensive branch-lines, especially in thinly-populated districts, the method of the traction-engine is of unquestionable advantage. Traction-engines are commonly fitted with two speeds—fast and slow,—one or other of which may be put in gear, according to the load. They are also fitted with steering apparatus, applied to the fore pair of wheels.

Bray's Traction-Engine Company, London, exhibited a traction-engine with feathering-wheels, the chief feature of which consists in the fitting

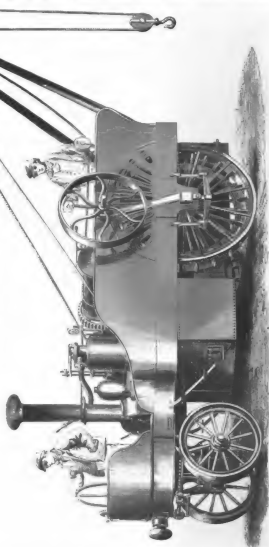
of the circumference of the driving-wheels with blades, teeth, or spades, as they have severally been called, which may be protruded through the circumference to any extent, to give grip or bite when required for adhesion, or altogether withdrawn, by means of a fixed excentric, similar in action to the feathering paddle-wheel. In many situations, the ordinary smooth surface of the wheel is sufficiently adhesive for propelling the engine with its load; but when the ground is soft or slippery, or when a steep incline has to be ascended, the auxiliary power of the blades may be brought into action, and the needful grip thereby obtained. The engine is fitted with two steam-cylinders, from which the power is transmitted to the driving-wheels by means of pinions on the crank-shaft, working into large circular racks bolted to the inner sides of the wheels, for the quick speed; or, by means of intermediate gearing, the engine may be put on the slow speed. The engine (fig. 314) which was exhibited, is fitted with a drum, by means of which it may be employed for driving machinery; a derrick is

also fitted to it, by which it may load its own waggons, and a capstan or windlass to give a purchase. The boiler is fitted into and fixed to the frame, without forming any portion of it, or being subject to any of the strain

Mr. Charles Burrell, Thetford, exhibited a *Boydell's traction-engine and endless railway*, the chief peculiarity of which consists in the endless railway, or wooden trams or shoes, transported by the wheels, laid down under them,

of working the engine. The driving-axle has four bearings—two inside and two outside the wheels,—for the purpose of steadying the engine; and the weight is placed on springs. Thus, in addition to its tractive power, the engine is qualified to act as a stationary or portable engine, a steam-crane, or a steam-winch, by which it has been well adapted for the service of Woolwich Dockyard, where it has been constantly and satisfactorily at work in its various capacities since it was removed from the Exhibition. A similar engine was employed in removing locomotive engines, marine engines, and other heavy machinery, from different railway-stations, manufactories, and docks, to the Exhibition building—the loads amounting, in some cases, to 45 tons. In a more recent design of the Bray engine (fig. 315), prepared by the Author, as consulting engineer to the company, the cylinders and gearing are ranged in a horizontal line with the driving-axle, by which the details have been simplified, and the cost of the engine reduced. A traction-engine has been constructed for the company on this system by Messrs. Chaplin & Co., of Glasgow, fitted with their upright boiler with tapered tubes. (Figs. 314 and 315.)

FIG. 314.

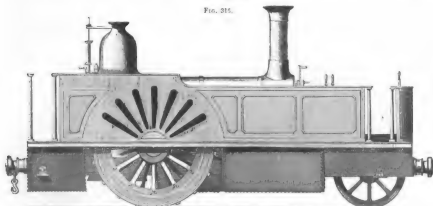


BRAY'S TRACTION ENGINE, BY BRAY'S TRACTION ENGINE COMPANY, LONDON.

to be run over in succession, and lifted again after having fulfilled the purpose of a railway. As the shoes are broad and flat, they afford a greater bearing for the wheel than when it runs directly upon the ground (fig. 316).

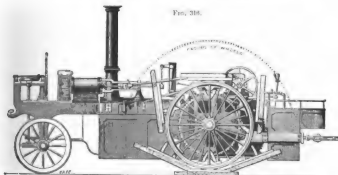
Messrs. Aveling & Porter, Rochester, exhi-

FIG. 315.



BRAY'S TRACTION-ENGINE (new design), by Bray's Traction-Engine Company.

FIG. 316.



BOYDELL'S TRACTION-ENGINE AND ENDLESS RAILWAY, by Mr. Charles Boydell, Thetford.

bited *Aveling's agricultural locomotive engine*. This engine has but one steam-cylinder, placed on the top of the boiler, surrounded by a steam-jacket, from the top of which the steam is conveyed into the cylinder. Thus the steam carries with it the condensed steam formed in the jacket into the cylinder. The crank-shaft is connected to the driving-wheels with but one speed, by means of an intermediate shaft with toothed gearing, from which the motion is transmitted by an endless chain over a chain-wheel on the driving-axle fitted with tightening gear, to take up the slack of the chain. The engine is steered in a peculiar manner, by means of a single disc-wheel in a triangular frame, projected from the leading axle in advance of the engine. This wheel is swivelled on a central pivot with a suitable lever, worked by the steersman, who occupies a seat in front of the engine. The rims of the driving-wheels, which are of cast-iron, are deeply indented, in order to give the necessary grip for propulsion. This engine is specially adapted as a locomotive

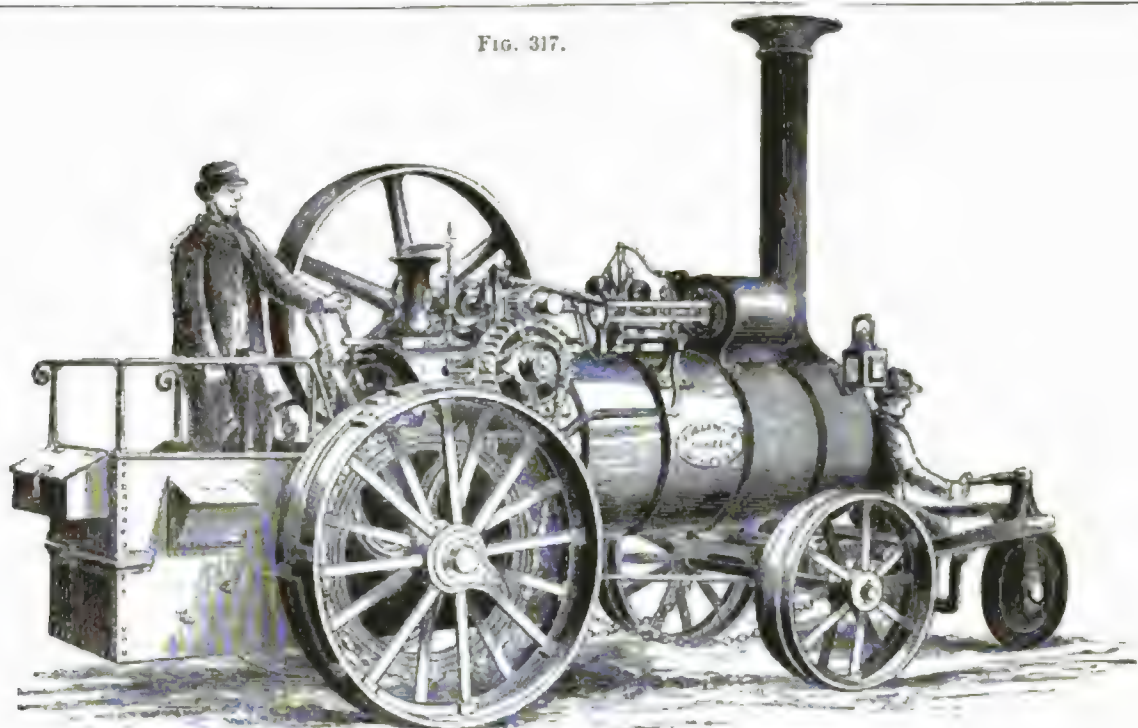
portable engine, to move readily about a farm, or from one farm to another, taking with it a thrashing-machine or other similar load (fig. 317).

Messrs. Robey & Co., Lincoln, exhibited a *traction-engine*, suitable also for working on farms as a portable engine. The driving-wheels are driven by means of pitch-chains, taken up when slack with a tightening screw (fig. 318).

Messrs. B. D. Taplin & Co., Lincoln, exhibited a *traction-engine* of 16 horse-power. The cylinders are placed within the smoke-box, and work to a pinion-shaft directly over and gearing into circular racks on the driving-wheels, which are placed under the barrel of the boiler and carry by much the greater part of the weight. The arrangements for steering are peculiar: the front wheels turn on separate centres close to the naves, and are guided by levers at right angles to the wheels, acted on by the steersman. The engineman and the steersman stand together on one platform, and the small wheels lead, the boiler going with its fire-box foremost.

Messrs. James Taylor & Co., Birkenhead,

FIG. 317.



TRACTION-ENGINE, by Messrs. Aveling & Porter, Rochester.

FIG. 319.

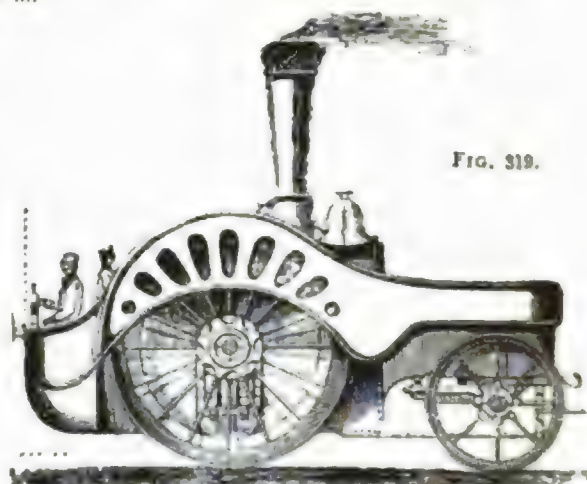


TRACTION-ENGINE, by Messrs. Robey & Co., Linc. In.

Mr. Charles B. King, London, exhibited a drawing of a *traction-engine* designed by him, with a locomotive boiler and wrought-iron framing, with buffers and buffer-planks at the ends, as in Mr. Clark's design already noticed. The cylinders are fixed at the fore part of the engine, and the crank-shaft works in plummer-blocks on the top of the fire-box, connected by spur-gear to the driving-wheels. The tyres of the driving-wheels are put on with an elastic medium to soften the shocks on the road. The engine is steered from the footplate behind the fire-box.

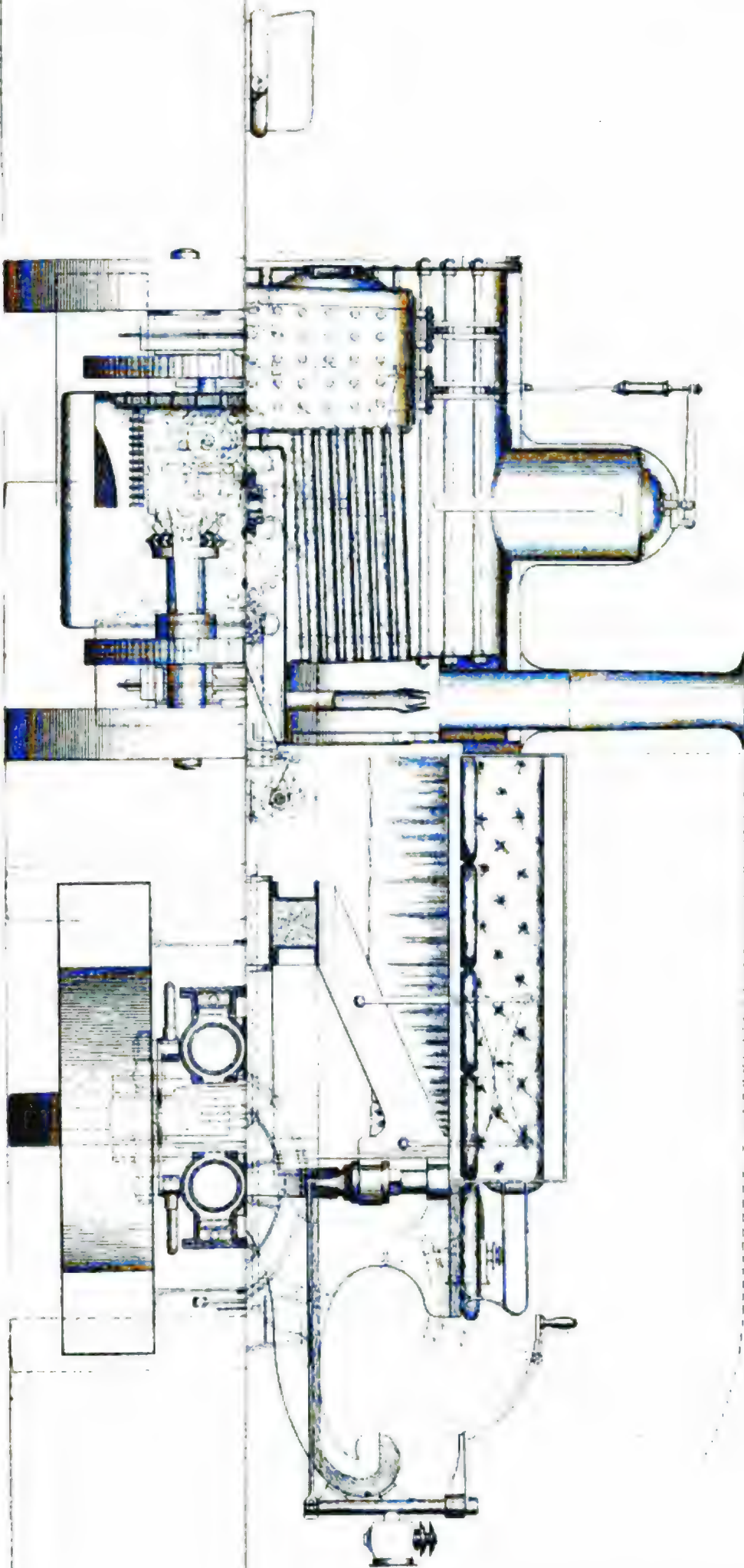
exhibited their "*steam elephant*," or *traction-engine*. It has three speeds, and the weight rests on blocks of india-rubber. The engine-man and steersman stand on one platform behind the driving-wheels, and the engine may run equally well going with either end foremost. The engine is provided with a winding apparatus, by means of which it can load its own trucks. The boiler is arranged to be as short as possible, with the object of ascending or descending steep hills without uncovering the fire-box or the flue-tubes; it rests on the frame of the engine, and is fixed to it without itself forming any part of the frame. The chimney passes through the dome of the boiler, in order to dry the steam (fig. 319).

FIG. 319.



STEAM-ELEPHANT TRACTION-ENGINE, by Messrs. James Taylor & Co., Birkenhead.

STEAM PASSENGER ROAD-CARRIAGE
 CONSTRUCTED FOR GEORGE SALT ESQ. SALTIAIRE.
 BY
 MESSRS CARRETT, MARSHALL, & CO. LEEDS.



CHAPTER XV.

STEAM-CARRIAGES.

Messrs. Carrett, Marshall, & Co., Leeds, exhibited a *steam passenger road-carriage* (see Plate XXIX), constructed for George Salt, Esq., of Saltaire. The following account of the steam-carriage is abstracted from a description supplied by the exhibitors:—It is designed as a private carriage to convey small excursion-parties, though there is power enough to take forty passengers almost as easily as the ten or twelve persons for whom the seats are arranged. The maximum power is 30 actual horse-power, and the total weight in complete running order is, with a supply of coal for thirty miles, and water for twelve miles, six tons. It can ascend any hill on a good turnpike road, even over new-laid metal; and can pass round quick curves, being able to pull up instantaneously on the steepest descent. It can attain a speed, on a good level road, of from fifteen to twenty miles per hour, and can run at an average speed of twelve miles per hour through an average country.

The boiler has 105 feet of effective heating-surface. The flue-tubes are 2 inches in diameter, and 2 feet 6 inches long, brazed into a copper fire-box, the sides of which are inclined. The short boiler-tubes favour the passage over steep gradients, and a low-pressure of exhaust steam, for which the valve-motion is specially designed. The boiler works at 150 lb. pressure, and is fitted with Clark's smoke-consuming apparatus.

The frames are of $\frac{3}{4}$ steel, attached to the back and front plates of the boiler, and are continued forward for the carriage department. A combined steel and wood frame is placed transversely over the cylinders; and a central longitudinal frame of steel from the smoke-box to the cross leading frame, to which the steering-spindle fork is attached. Thus a firm and light support is given to each of the cross frames. The slides of the main axle are inclined, so as to divert percussive action from the main springs in going forward, and to keep the spur-gear at its proper centres. The weight of the boiler and the principal part of machinery, amounting to $5\frac{1}{2}$ tons, is borne by the driving-wheels, which may be reversed and skidded when it is necessary to stop instantly. An ordinary brake is provided.

The motion consists of spur-gear in duplicate in the ratio of 5 to 1, with which the pistons attain a speed of 650 feet per minute, or about half the speed of the carriage. If the carriage were arranged for 40 passengers the gearing would be in the ratio of about 7 to 1.

For the easy working of the gearing, as the driving-wheels are frequently moved at different speeds, "Roberts' universal differential motion" is applied to the main axle. The gearing in connection with the differential gear is specially adapted to suit itself to the varying inclinations of the driving-axle on uneven roads. As it is

new, it merits a particular description. The main shaft (κ) is a bolt or bar, with its centre cross-pin and two bevel wheels or couplings ($J J$) free to move any way; on this centre bar the other two bevel wheels ($L L$) and the two driving-wheels ($M M$) are respectively connected firmly together by wrought-iron hollow shafts, moving free upon the centre shaft. Upon these external shafts the spur-wheels ($N N$) are fitted freely, and are driven by the two pinions ($I I$) fast on the first-motion crank-axle. The two spur-wheels ($N N$) move the first two bevels and also the central shaft by two driving-bars ($J J$), each of which moves freely on its three points of contact, and thus allow the two spur-wheels to keep in connection with their respective pinions, in all the relative positions of the two axles. Their united power is transmitted to the central bevel wheels through the two universal driving-bars ($J J$). When the carriage moves along a straight road the bevel wheels merely perform the office of circular clutch-couplings; but on passing round curves, they give way and admit of either driving-wheel taking the inner curve, and even if necessary to become stationary whilst the other wheel makes a circuit round it.

The driving-wheels are 4 feet in diameter and 7 inches wide. They consist of a cast boss with steel spokes and rim, fitted with outer wood segments and exterior tire. Wearing segments are bolted to the tire, and may be readily replaced. The cylinders ($Z Z$) are 6 inches in diameter with 8-inch stroke, with an ordinary link-motion, and, in addition, an expansion link-motion for forward gear, giving a free exhaust, and cutting off up to one-fifth of the stroke. Gray's variable blast-pipe is applied. The regulator is closed by the reversing lever when reversed.

The steering is effected with ease; there is but one leading wheel, and the obstructions of the road are resisted by the vertical axis, which is a forked steering-shaft. It is allowed to rise and fall as well as to turn freely, by means of a parallel motion by which the longitudinal strains are received by a fixed pin level with its axle, and made fast to the frame between the cylinders. The parallel rods ($F F$) have a universal hold of a beam lever, and also of the axle of the leading wheel, so that any shock received by the wheel in any position is transmitted to the frame.

The coke or coal bunkers carry 6 cwt., which suffices for a journey of 30 miles. The water-tank holds 150 gallons, which can be heated by the waste steam. The boiler is fed by a pump worked by the engine, and by a donkey pump in addition, to be used when the carriage is not in motion.

Messrs. Yarrow & Hilditch, London, exhibited a *steam passenger-carriage* for common roads, constructed to carry twelve passengers. It was built by Mr. T. W. Cowan, Greenwich. The main frames are made of ash $4\frac{1}{2}$ inches deep, plated on both sides with $\frac{1}{4}$ -inch iron; they carry two iron foundation-plates for

the cylinders and other working parts. The driving-wheels are 3 feet in diameter and 3 inches broad, with outside bearings, and overhung cranks to which the cylinders are connected directly, without the intervention of gearing.

To maintain a uniform distance between the cylinders and the axle under the play of the springs, on which the weight is supported, links are substituted for axle-box guides; causing the axle to play in a curve. Thus the action of the slide-valves is not interfered with, and the wear and tear of guides is avoided. The working parts are protected from dust by a sheet-iron casing. The cylinders are 5 inches in diameter with a 9-inch stroke. The boiler is upright, and tubular, with a steel shell 2 feet in diameter and 3 feet 6 inches high; it has 65 square feet of heating-surface, and a firegrate 20 inches in diameter. The steering is effected by means of a chain, the ends of which are attached to a wheel-plate and passed round a worm fixed on an upright spindle, with a hand-wheel. A reversing-lever and a brake are also placed within the reach and control of the steersman. The water-tanks are placed under the seats, and the fuel is carried in the tender. The gauge of the front or steering wheels is 5 feet 6 inches. That of the driving-wheels is only 3 feet 3 inches, the narrowness of which facilitates turning corners

without throwing either of the wheels out of gear. With 50 lb. to 70 lb. steam the carriage can be started with the front wheels fully locked. The total weight of the carriage, fully loaded, is $2\frac{1}{2}$ tons, of which about 34 cwt. is on the driving-wheels and 11 cwt. on the front wheels. The carriage is reported to have ascended a slope of 1 in 20 with ease, and to have attained a speed of from 15 to 18 miles per hour on a level road. For large carriages horizontal boilers are used, placed directly over the driving-axle, with the water-tanks underneath. The body of the carriage is made like that of an omnibus, excepting that passengers enter at the front, and it completely encloses the boiler and engines.

In carriages that have been built for use in the West Indies, the driving-wheels are 4 feet in diameter, with tires 4 inches broad, and 3 feet 9 inches gauge. The front wheels have 5 feet 6 inches gauge. The axles are 9 feet apart, and the length over all is 16 feet 6 inches. The horizontal boiler is 3 feet in diameter and 4 feet long, with an internal flue and return tubes. The exhaust steam may be condensed for short periods, when any difficulty from the noise is experienced. With the exception of the chimney and steering apparatus, the carriage is similar in outward appearance to an ordinary vehicle.

SECTION II.

MARINE ENGINES.

CHAPTER I.

INTRODUCTORY REMARKS.

The display of marine engines, though necessarily limited, was varied, and embraced the leading types of construction. In 1851, paddle-engines, in various forms, were chiefly exhibited, and one or two screw-engines were added. In 1862, screw-engines, in various forms, were chiefly exhibited, and one or two paddle-engines were added. Whence it appears that the paddle has been, to a great extent, superseded by the screw for marine propulsion; for war purposes entirely so, for at least one obvious reason,—that the screw system of propulsion offers facilities for disposing of the whole of the machinery considerably below the water-line, for the sake of general stability, and of working with comparative safety out of the direct reach of shot. But the necessity for placing the machinery in the lowest practicable position, and disposing it with its greater dimensions transversely to the hull of the vessel, has enforced the adoption of special expedients for disposing the

engine compactly and equally on both sides of the crank-shaft. In these modifications or departures from the normal form of engine, consisted the chief interest of the display; and the chief condition which regulated the design, was the recognized necessity for providing a sufficient length of connecting-rod. In the placing of screw-engines, it may be said that constructors uniformly place the cylinders on one side of the crank-shaft, and the pumps and condensers on the other side. The divergence in detail lies in the means of connecting the cylinder to the crank-shaft, which has been treated in three ways—by the return connecting-rod, by means of the trunk, and by the short connecting-rod,—typified respectively in the engines of Messrs. Maudslay, Sons, & Field, Messrs. John Penn & Son, and Messrs. Humphrys & Tennant, and illustrated by the subjoined block elevations, with the same proportions of cylinder. The method of the return rod, No. 1, gives a connecting-rod of five times the length of the crank, and occupies the shortest length of space, admitting of the cylinders being placed closer to the crank-shaft than in other

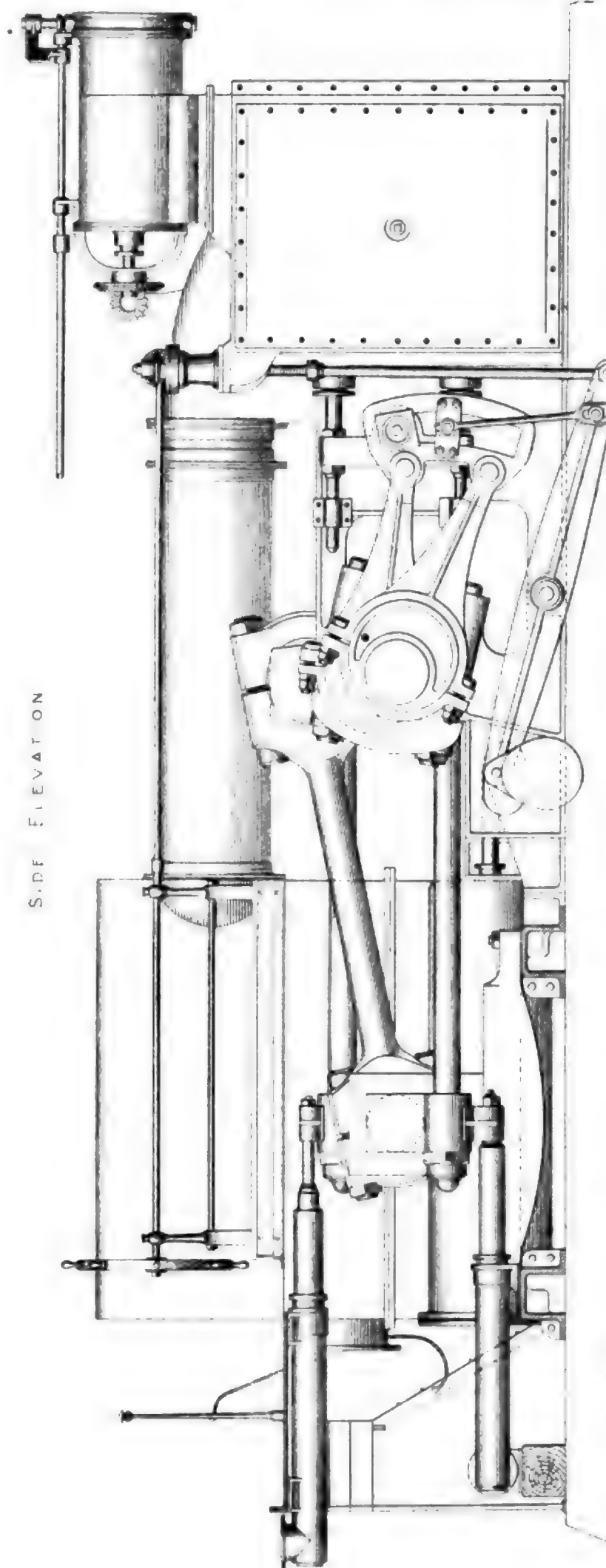
PAIR OF HORIZONTAL DIRECT-ACTING SCREW ENGINES FOR H.M.S. "PRINCE CONSORT"

OF 1000 COLLECTIVE NOMINAL HORSE POWER

BY

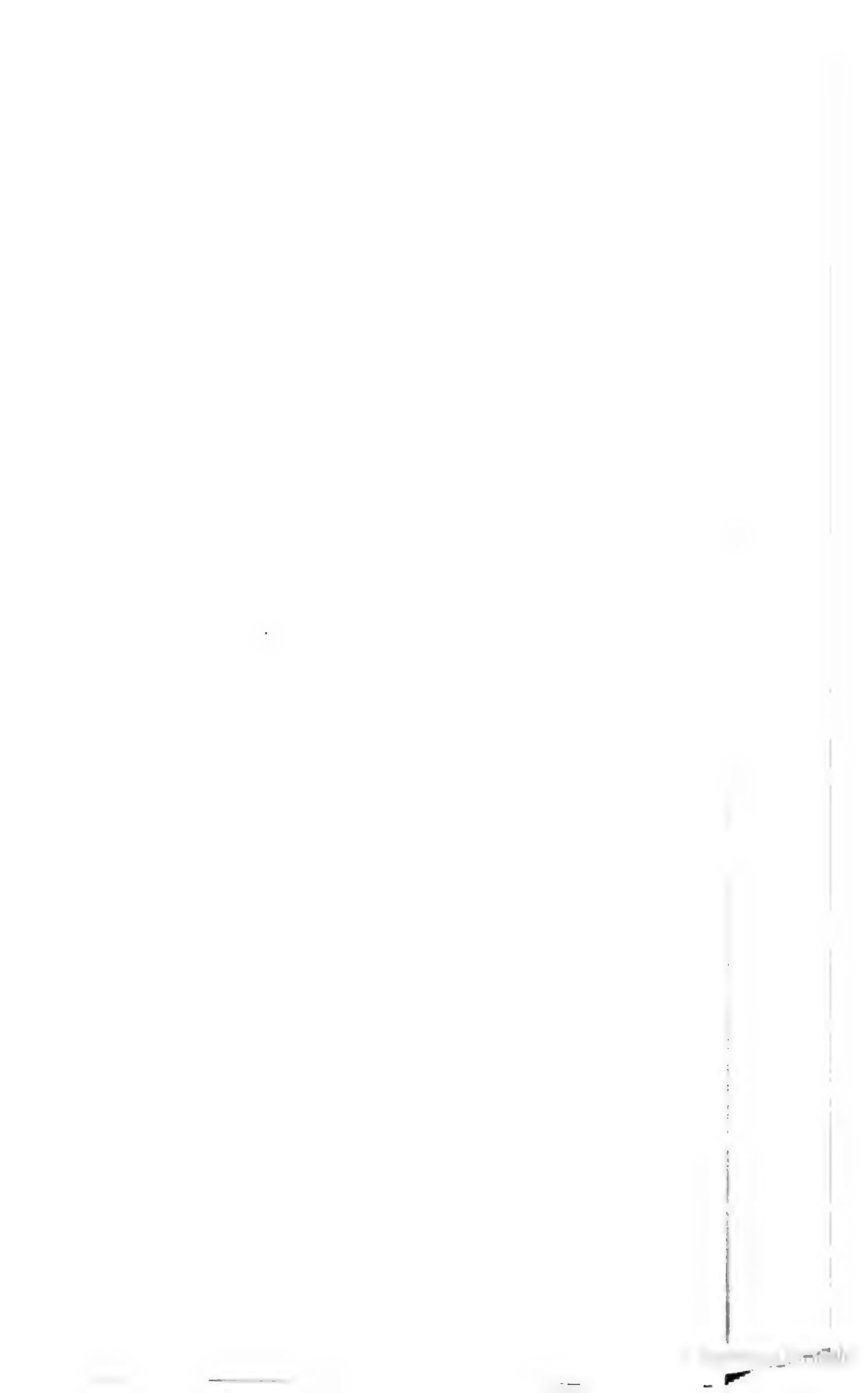
MESSRS MAUDSLAY, SONS, & FIELD, LONDON.

SIDE ELEVATION

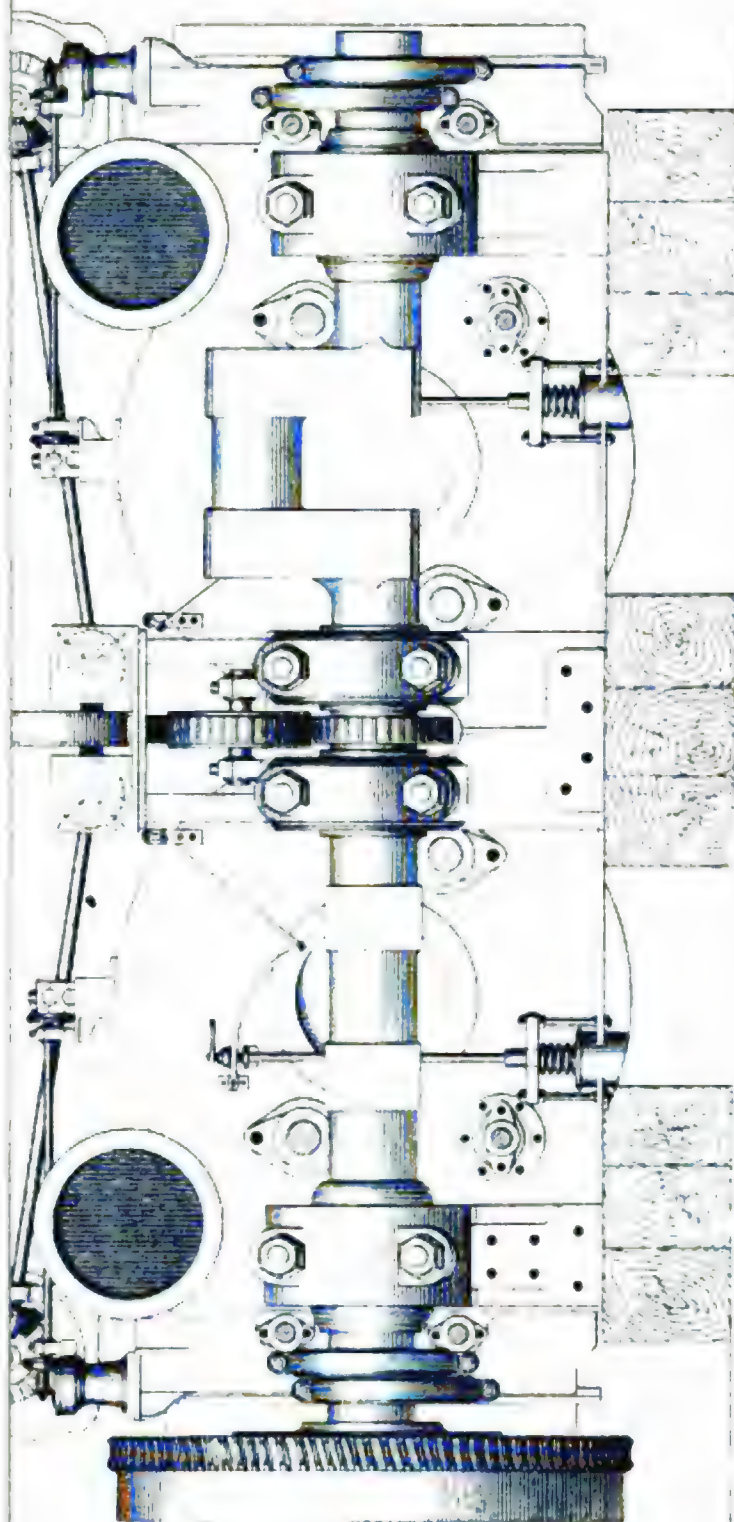


SCALE $\frac{1}{4}$ INCH TO ONE FOOT





PAIR OF HORIZONTAL DIRECT-ACTING SCREW ENGINES FOR H.M.S. "PRINCE CONSORT"
OF 1000 COLLECTIVE NOMINAL HORSE POWER
BY
MESSRS MAUDSLAY, SON & FIELD, LONDON



Drawn by J. H. H. & Co. for the Admiralty

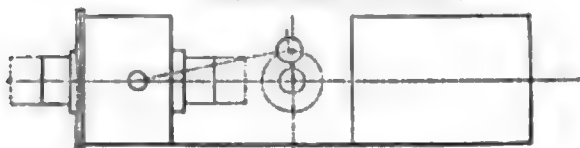
forms of engine; the trunk, No. 2, also affords a five-length connecting-rod; and the short rod, No. 3, is only three and a half times the length of the crank, whilst it occupies about the same

FIGS. 320.

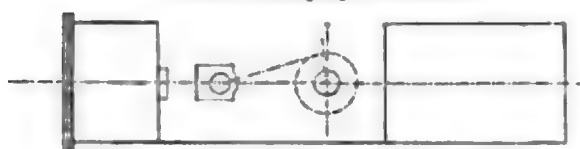
No. 1.—Maudslay, Sons, & Field.



No. 2.—John Penn & Son.



No. 3.—Humphrys & Tennant.



No. 4.—Ordinary Engine.



BLOCK ELEVATIONS OF SCREW-ENGINES, to show their proportional lengths.

space as the trunk-engine—not allowing, however, for the horizontal play of the trunk, which requires additional space; No. 4 represents an ordinary engine with a connecting-rod five times the length of crank, occupying the greatest length of all (figs. 320).

For mercantile purposes, the upright inverted-cylinder engine is much in favour, and has been fairly represented.

CHAPTER II.

MARINE ENGINES EXHIBITED BY MESSRS.
MAUDSLAY, SONS, AND FIELD.

Messrs. Maudslay, Sons, & Field, London, exhibited the *horizontal direct-acting screw-engines* of H.M.S. *Valiant*, iron-plated, together with a number of finished *working models of marine engines*. Amongst these models, those of the engines for H.M.S. *Prince Consort* and *Octavia* are most deserving of notice, as the former comprises the most recent touches of improvement in the system of the return connecting-rod, and the latter embodies an effective arrangement with three cylinders, specially designed for regularity of motion, and for economical expansive-working.

1. The horizontal direct-acting screw-engines for H.M.S. *Prince Consort*, of 1,000 nominal horse-

power. (Plates XXX and XXXI.) The cylinders of these engines are 92 inches in diameter, with a 4-feet stroke of piston, and a connecting-rod 10 feet in length. Working at full power, the engines make from 55 to 60 revolutions per minute; and they have indicated a maximum of 4,234-horse power. As before observed, these engines are so arranged that, while they occupy the lowest possible position in the vessel, they admit of the use of a comparatively long connecting-rod, thereby reducing the thrust or pressure upon the crosshead-guides. There are two long piston-rods, one passing over and the other under the crank-shaft, from which the system is commonly known as that of the double piston-rod. The two rods are united in a diagonally-formed crosshead on the other side of the crank-shaft, from which the connecting-rod works back to the crank. The slipper-guide for the crosshead consists of a sliding surface on the bed of the engine, fitted with adjustable wearing pieces, upon which the crosshead works, and upon which the whole thrust of the connecting-rod is delivered. It overlaps the foot of the crosshead on both sides by oblique bearings with V pieces, and so resists the upward strain of the connecting-rod when the engines are reversed. The crank-shaft, in proximity to the cylinders, works in plummer-blocks which are in single castings of great depth, bolted to the cylinders, forming a connection of great strength and stiffness.

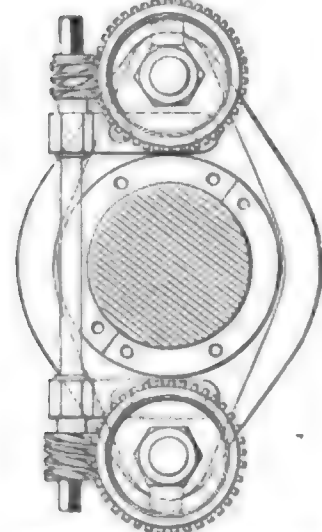
The slide-valves cut off the steam at five-eighths of the stroke; they are placed vertically on the sides of the cylinders, and are worked direct from the crank-shaft by the ordinary link-motion, with solid gun-metal excentric-rods cast in one piece with the half-strap. The link-motion is used only for starting and reversing the engines, not as expansion-gear. The valves are of the gridiron form, or double-ported, and, compared with single-ported valves, they have only half the travel, and enable the engines to be more quickly reversed, with only half the power to work them. They are fitted with equilibrium-rings on their backs, to relieve them of the steam-pressure, the interior of the rings being in communication with the condenser. The link for working the slide-valves is lowered upon and carried by the block, through which the motion is transmitted to the valve; and thus any play or slip of the block in the link is prevented. The sustaining bar is made with a slot-hole in its lower end, to allow for play. Variable expansive-working, by cutting off at from one-sixth to five-sixths of the stroke, is separately provided for by means of revolving equilibrium-valves, with four openings for steam, which, with the throttle-valves, are placed immediately on the tops of the slide-jackets, and are driven by gearing from the crank-shaft, making one revolution to two of the crank-shaft. The adjustment of the valve for various degrees of expansive working is effected

by turning it upon the spindle by which it is carried and driven, so as to change the position of the openings by advance or by recession, and so, in the course of its revolution, to cut off the steam at an earlier or a later point of the stroke. The valve is shifted by means of a sliding-feather, fitted into a straight groove in the spindle, and into a spiral slot in a long socket attached to the valve; the feather, being advanced or withdrawn longitudinally upon the spindle, shifts the valve radially to the needful extent. The engines may be started in any position by working or reversing the links separately, which are so arranged for the purpose, by which the engine can be backed.

The cylinders are covered with steam-jackets, inclosing a $2\frac{1}{4}$ -inch space, in which they are completely enveloped. The jackets are supplied with steam directly from the main steam-pipe; one pipe takes steam to the circumference and front, and another to the cylinder-covers at the back, independently of the supply of steam to the cylinder itself. The piston-rod glands are fitted with worm-wheels and a tangent-screw, by which they may be turned simultaneously and in equal degrees, and may be tightened with ease and safety whilst the engines are working (fig. 321). The relief-valves at the ends of the

cylinders may be eased by means of levers worked from the platform, by which the springs are lifted off the valves, in case of any water from condensation or priming collecting in the cylinders. By thus permitting the valves to lift freely, the water easily escapes from the cylinders, and the risk of damage is avoided. The steam-pipes, of copper, are made with an expansion-joint, constructed by forming broad flanges on the ends of the pipes, and bolting them together at their circumferences with brass rings interposed and brazed to them, to give the necessary clearance for contraction between the ends of the pipes.

FIG. 321.
PISTON-ROD GLANDS, for Marine Engines, by Messrs. Maudslay, Sons, & Field, London.



The condensers and air-pumps, on the other side of the crank-shaft, are separated, and disposed at the outer sides of the engine, leaving an open space for the engineer's platform, in an elevated position, from which the principal working parts of the engines can be freely observed and easily got at whilst in motion. The condensers being thus placed widely apart, and opposite the valve-chests, the steam is directly discharged through straight eduction-pipes, in which the upward bends

usually required to enable the pipes to clear the cranks are entirely obviated. The air-pumps are double-acting, and are worked direct by rods from the pistons, one to each pump, working through the cylinder-covers with stuffing-boxes. The air-pumps are lined with gun-metal, $\frac{1}{4}$ inch thick, and are fitted with india-rubber foot and delivery valves on gun-metal seats. The condensers are placed altogether above the level of the air-pumps, giving a fall towards the pumps, and so improving the vacuums. The feed and the bilge-pumps are placed under the platform, and are worked from the cylinder-crossheads; the valve-boxes are easily accessible, and may be separately examined while the engine is at work. The hand-pump may be worked off the end of the crank-shaft, by a pin adjustable in a V-slide by a screw and nut, to give any required length of stroke. All the shaft-"brasses" consist of white metal run into gun-metal cases.

The engines may be turned by manual power by means of a large worm-wheel on the end of the crank-shaft. A counterbalance-weight, for the cranks, is bolted to this wheel.

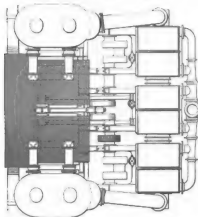
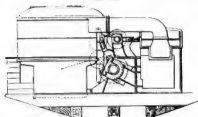
There are eight boilers, having an aggregate heating surface of 20,300 square feet, or 20·3 feet per nominal horse-power.

The engines, boilers, screw-shaft, and propeller weigh altogether, with water in the boilers, 750 tons. The ship is 277 feet long, 58 feet broad, and has 19 feet 10 inches depth of hold. Her tonnage is 4,045 tons. She carries eleven 120-pounder guns, and twenty 68-pounder guns, weighing in all 120 tons; besides 1,100 tons of armour-plates.

2. *Horizontal Three-cylinder Screw-Engines*, of H.M.S. *Octavia*, 51-gun frigate, of 500 nominal horse-power, represented by a working model (figs. 322). These engines were designed on the double piston-rod principle, for working with great economy of fuel, by steam-jacketing the cylinders and considerably expanding the steam, with surface-condensation, and the use of superheated steam; combined with uniformity of motion and equable power, to do away with the vibration of the vessel incidental to the action of two cylinders. There are three cylinders, each 66 inches in diameter, with a stroke of 3 feet 6 inches, working to a crank-shaft, with the cranks equally distributed at angles of 120° . The steam-jackets are applied to the circumferences and the ends of the cylinders; and it is intended to work with steam at from 20 lb. to 25 lb. pressure per square inch. The collective sectional area of the three cylinders is about one-half more than the area necessary for ordinary engines of two cylinders for the same power. The connecting-rods are 6 feet 6 inches long—only $3\frac{1}{2}$ times the length of the crank. Special expansion-valves being dispensed with, the steam is cut off entirely by the slide-valves, which are double, and are placed on the upper side of the cylinders; they are also double-

ported, with an additional, third, opening at each end, "to give the requisite area of opening for the steam-port." The two ports in each valve are each 2 feet 7 inches long, by $2\frac{1}{2}$ inches wide, and the additional opening is $\frac{1}{2}$ inch wide.

FIGS. 321.



HORIZONTAL THREE-CYLINDER SCREW-ENGINES, of 500-horse power, by Messrs. Maudslay, Sons, & Field, London.

The valves are set to cut off at from one-fourth to one-seventh of the stroke. They are worked by a smaller crank-shaft placed across the engine immediately in front of the slide-jackets, and driven from the main crank-shaft by means of spur-gearing, of which two intermediate spur-wheels are mounted in a movable frame, which may be raised or lowered from the platform, whilst in gear with the spur-wheels on the crank-shafts. By so changing their angular position with respect to the main

crank-shaft, the upper crank-shaft is shifted radially, and the valves are caused to cut off earlier or later as may be required. The same gearing is used for starting and reversing the engines, as the position of the slide-cranks may be altered sufficiently for the purpose; they may be set back so far as to allow the steam to "dwell on" for about the stroke, for starting.

Two of Hall's surface-condensers are applied; they are placed on the extreme right and left of the engine, with the platform between them, from which the machinery is easily observed. They are similar to those applied by the exhibitors to the engines of H.M.S. *Grapppler*, in 1842, in which the condensing water surrounds the tubes, the steam being inside. Each condenser is fitted with $\frac{1}{2}$ -inch copper tubes, No. 18 wire-gauge in thickness, having an aggregate length of $5\frac{1}{2}$ miles. The condensing water is driven through the condensers by two double-acting solid-piston pumps, fitted with lignum-vite packing, driven direct from the pistons of the outer cylinders. The air-pumps are also placed opposite the outer cylinders, and are worked each by a bracket from one of the piston-rods.

The steam is superheated by an apparatus invented by the late Mr. Field in 1859—a number of flattened iron tubes, placed in the uptake of the boiler, which are traversed by the steam on its way to the engine. The ends of the tubes are circular and are fixed in tube-plates, from which defective tubes may be withdrawn and replaced. The feed-water is heated in a narrow chamber or casing, 2 inches wide, on the front of the superheater, before it passes into the boiler. The boilers are worked at the usual Admiralty pressure, 20lb. per square inch, and are a third less in size than those commonly provided for the same power of engine.

The machinery of the *Ostrea* was constructed by order of the Admiralty with a view to illustrate and experiment upon the various known means of effecting economy of fuel; the vessel being a converted frigate designed by Sir William Symonds. At the official trial in Stokes Bay, in November, 1862, the vessel was propelled by a Griffiths screw, 18 feet in diameter, and 20-feet pitch, and attained a speed at full power of $12\frac{1}{2}$ knots per hour, making 70 revolutions per minute, with a steady pressure of 20lb. per inch in the boiler, and a vacuum of $28\frac{1}{2}$ inches of mercury. It is expected that the consumption of fuel will be about one-half of that of ordinary engines of equal power (figs. 322). At the trial trip, $2\frac{1}{2}$ lb. of coal was consumed per indicator horse-power. A considerable saving of fuel has also been realized in several vessels running between London and the Mediterranean ports, recently fitted with engines of this description, of 150 nominal horse-power, fitted with Hall's surface-condensers. Working with steam of 22lb. pressure per square inch, and a steady vacuum of from $26\frac{1}{2}$ to $27\frac{1}{2}$ inches of mercury,

the ordinary consumption of coal is about $2\frac{1}{2}$ lb. per indicator horse-power.

3. *Horizontal Direct-acting Screw-Engines*, with double piston-rods, constructed for H.M. armour-plated screw-ship *Valiant*, collectively of 800 nominal horse-power, with 82-inch cylinders, 4-feet stroke, and making 60 revolutions per minute at full power. The general design of these engines is immediately antecedent to that of the *Prince Consort's* engines, and was brought out twelve years ago, just after the Great Exhibition of 1851. They are, in all probability, to be the last of their class. In the general arrangement these engines are similar to those of the *Prince Consort* already described, excepting that the condensers and air-pumps are placed low and in the middle, and there are double guides for the crossheads. They comprise the novel features of the latter, with the important exception that the valve-gear, which is direct in the *Prince Consort*, is inverted in the *Valiant*, inasmuch as the link-motion works to a rocking-shaft over the condensers, from which the valves, placed on the top of the cylinders, are worked by return-rods. There are, in fact, two valves to each cylinder, working simultaneously over the steam-ports, which are in two breadths, and admit of a stronger cylinder-casting and shorter passages than if in one breadth. The intervention of the rocking-shaft admitted of the use of excentric-rods of great length, a feature in which they contrasted favourably with the short direct rods of the *Prince Consort*; but it involved a great deal of mechanism, which has been entirely swept away in the more recent engines. In these, it is true, the excentric-rods are very short, and would, if the link were used for expansive-working, incur an objectionable extent of slip between the block and the link; but the duty of the link being confined to the working of the slides in full gear with a fixed cut-off, it is allowed, by a happy contrivance, to rest solidly on the block when going ahead, and the slip is thereby eliminated, whilst a steadier movement is obtained.

4. *Horizontal Direct-acting Screw-Engines*, with double piston-rods, exhibited in model, for H.M. armour-plated iron ship *Agincourt*, of 1,350 nominal horse-power. The cylinders are 101 inches in diameter, with a stroke of 4 feet 6 inches. The slide-valves are double-ported, worked by the link-motion, and they, with the expansion-gear and other recent appliances, are similar to the fittings of the *Prince Consort*. The valves are each in two distinct pieces, placed one above the other, edge to edge, with separate rods. They are, of course, simultaneous in their movements, and they admit of a stronger cylinder-casting, with two half steam-ports in place of one long one.

5. *Horizontal Direct-acting Screw-Engines*, with double piston-rods, exhibited in model, for

vessels of light draught. These engines, of 200 nominal horse-power, have been applied to H.M. steam-sloops, *Mutine* and *Cameleon*, of 17 guns, and to several despatch-vessels in the British and foreign navies.

6. *Oscillating-cylinder Paddle-Engines*, direct acting, exhibited in model. Engines of this class have been fitted on board the Royal Mail steam-ship *Mersey*, of 250 nominal horse power, and several other fast passenger-ships.

7. *Direct-acting Marine Screw-Engines*, with double piston-rod, exhibited in model, for H.M.S. *Victoria*, of 131 guns, and the *Mersey* frigate, of 40 guns; of 1,000 nominal horse-power, with 92-inch cylinders, and 4-feet stroke, resembling the engines of the *Valiant*.

8. *Upright Annular Cylinder-Engines*, in model, designed by the late Mr. Joseph Maudslay, for driving the screw on board merchant ships and private yachts.

9. *Feathering Screw*, in model, designed by the late Mr. Joseph Maudslay. This propeller has been for several years worked with success on board the vessels of the late General Screw Steam Shipping Company; and has recently been fitted to H.M. steam-frigate *Aurora*, of 400 nominal horse-power, and 51 guns. The pitch can be readily changed from the deck, while the engines are at full speed; and when the ship is under sail only, the blades may be placed in a fore and aft position, parallel to the keel, so as to offer a minimum resistance to the progress of the ship, and to obviate the necessity for raising the screw when sailing.

10. *A Crosshead and a Connecting-rod* for the engines of the *Agincourt*, well forged and finished.

CHAPTER III.

MARINE ENGINES EXHIBITED BY MESSRS.
JOHN PENN AND SON.

Messrs. John Penn & Son, Greenwich, exhibited a pair of *horizontal-trunk engines*, collectively of 600 nominal horse-power, to drive the screw, 18 feet in diameter, on board the first-class frigate the *Gerona*, in the Spanish navy. The trunks, made in one piece with the pistons, work through both ends of the cylinder, and the connecting-rod has its bearing upon and within the trunk at the middle of its length, taking the whole of the thrust of the connecting-rod, and so dispensing with the ordinary guides and piston-rods. The cylinders are 6 feet 6 inches in diameter, with a 3 feet 6 inch stroke; the trunk is 2 feet $8\frac{3}{4}$ inches in diameter, with a sectional area of between a fifth and

a sixth of the cylinder, leaving a working area of piston equal to that of an ordinary piston of 5 feet 11 inches in diameter; the maximum speed at full power is 64 revolutions per minute, with steam of 20 lb. pressure per inch. The valves are ordinary slides placed vertically on the outer sides of the cylinders, and moved directly by outside link-motions from the crank-shaft. A small auxiliary valve is placed upon the top of each cylinder, with steam-passages to the cylinders to supply steam from the main to start and reverse the engines by hand, when necessary, as the links do not in all positions admit of the main ports being opened for steam—the slides being made with considerable lap,—and there is no provision for working them separately. Expansion-gear is applied, moved by a series of small cams on the crank-shaft which work a reciprocating valve; but with the link-motion alone the steam may be cut off at from three-eighths to five-eighths of the stroke. The action of the cams is taken off by a friction-roller, which is held in contact by means of a vacuum-cylinder and piston. The cylinders are covered with felt and wood on their sides; but the ends and the trunks are bare. The cranks are fitted with balance-weights, one strapped upon each crank-arm, to aid in neutralizing the momentum of the trunk and other reciprocating and revolving pieces. The crank-shaft is $13\frac{1}{2}$ inches in diameter, and has remarkably long bearings,—30 inches in length; it is carried in cast-iron A-shaped or triangular frames bolted to the cylinders.

The air-pumps and condensers are opposite to the cylinders. The pumps are worked by rods direct from the pistons, and they consist of a solid piston working in a cylinder open at both ends, in free communication with the valves, which are of india-rubber, having gun-metal seats in a horizontal plate over the barrel. The exhaust steam passes through pipes over the crank-shaft to the condensers. The whole of the engine is firmly bolted down to its foundation.

The feed and bilge pumps on each side of the engine are fixed upon the outside of the condensers, and are worked in a line by one plunger worked by a rod direct from the piston. A worm-wheel is fitted on the crank-shaft, by which it may be turned by hand when required.

The heating surface of the boiler amounts to 11,000 square feet, or 18·3 square feet per nominal horse-power.

Messrs. John Penn & Son also exhibited very perfect pieces of workmanship, the result of the application of tools to the finishing of nearly every detail, without the aid of handwork:—A crank-shaft for the *Achilles*, an expansion-link most delicately finished by tools, a large cylinder, with its cover—one of the *Achilles*—finished like watchwork, a very fine specimen of loam-casting, sharply defined; also, a model of the oscillating-cylinder engines and paddles on board the Thames river-boats.

CHAPTER IV.

MARINE ENGINES EXHIBITED BY MESSRS. HUMPHRYS AND TENNANT.

Messrs. Humphrys & Tennant, Deptford, exhibited a pair of *horizontal direct-acting screw-engines* of 400 nominal horse-power, for H.M.S. *North Star*, in which the connections of the cylinders and cranks are like those of an ordinary direct-acting steam-engine. The exhibitors have dealt with the usual difficulty of confined space by shortening the connecting-rod,—thereby approximating the cylinders to the crank-shaft, and to a great extent balancing them by the condenser and pumps on the other side of the shaft. The cylinders are 64 inches in diameter, with 32 inches of stroke. They are not steam-jacketed, and the exhaust steam is discharged into an exhaust-chamber, cast in one piece with and over them, common to both, on the way to the eduction-pipe. The relief-valves are cast with two-way 3-inch cocks, which are connected together, and may be instantly opened by hand, to let off any sudden accumulation of water in the cylinders, whilst the relief-valves themselves remain closed to the atmosphere.

The slide-valves are double-ported; they are applied vertically at the outer sides of the cylinders, and are worked by a link-motion direct from the crank-shaft, employed for all the purposes of starting, reversing, and expansive-working, without any additional gearing. The valves cut off at two-thirds of the stroke, in full gear. The excentric-hoops are lined with a strip of rolled brass, $\frac{3}{8}$ inch thick, laid in and free to slide with the excentric or the hoop. The link is formed of a simple curved bar, 4 inches broad by $3\frac{1}{2}$ inches thick, called the bar-link. In itself it is simple and strong, but it involves the use of an elaborate cylindrical joint, adaptable to the varying obliquity of the link, to transmit the motion to the valve-spindle. Every wearing surface is carefully provided with means of adjustment. The reversing-rod is worked from the side of the condensers, low down.

The connecting-rod is 4 feet 8 inches long, or $3\frac{1}{2}$ times the length of the crank; it is forged with solid ends and caps,—simple and substantial. The crosshead works in a slipper-guide on the base-plate, turned square over upon the edges of the guide to resist upward strains; the gun-metal bearings, in two pieces, being produced so as to form the slide. The slide is fitted with a wearing piece below, formed with recesses 2 inches in diameter, to hold white metal for wearing. A water-pipe is provided to turn on water and cool the guide should it heat. The crank-shaft is $13\frac{1}{2}$ inches in diameter, and the length of its bearings is twice the diameter, 25 inches.

There are only one condenser and one central eduction-pipe, direct from the cylinders to the condenser, to which the engine is partly indebted for its peculiar air of simplicity. The eduction-

pipe is straight, obviating, in virtue of its central position, the usual necessity for being bent in order to clear the cranks. There are two air-pumps within the condenser, worked direct by rods from the steam-pistons. As there is but one condenser with the air-pumps to balance the cylinders; and as, on the contrary, the cylinders are necessarily placed at some distance from the shaft, the former, in order to counterbalance the latter, are placed out to a proportionally greater extent from the shaft than is usual with double condensers; but the intervening space is utilized by making a convenient passage across the engine behind the shaft. The eduction-pipe is made with a sliding or stuffing-box joint, to adapt itself to the regular working of the engine, which is perceptible; the steam-pipe is made with the box expansion-joint, which yields sufficiently for the purpose. The feed or bilge pumps are worked by rods from the pistons; they are double acting, and are serviceable for both purposes,—feeding the boiler, or discharging bilge-water.

The central portion of the engine is cast in one piece or base, extending the whole width across the engine, and having the three plumb-blocks for the crank-shaft cast solid upon it. The slipper-guides for the crossheads are bolted to it. The outer bearings for the crank-shaft are stayed to the upper parts of the cylinders by turned wrought-iron struts, which are less obstructive to the view of the engine than the usual A-frame of cast-iron would be. The central piece is bolted down to the keel, and the outer pieces—the cylinders, and the air-pumps and condenser—are laid, not bolted down, so that in the event of the sides of the ship settling, the engine is free to follow the change of level in the floor, or to suspend itself, as possibly the cylinders may do, upon the middle piece.

With 19 square feet of heating surface per nominal horse-power, engines of this power have, with steam of 24 lb. pressure per inch, exerted a force of 1,834 indicator horse-power, more than four and a half times the nominal power.

Messrs. Humphrys & Tennant exhibited also a model of a pair of direct-acting double-cylinder inverted engines, for driving the screw-propeller of the Peninsular and Oriental Steam Navigation Company's ship *Mooltan*, of 400 nominal horse-power. The cylinders are steam-jacketed, and are constructed in pairs for expansive working, on Woolf's system, the smaller cylinder being above the larger one—end to end with it. They are respectively 96 and 43 inches in diameter; the pistons on one rod, with 3-feet stroke, making from 60 to 65 revolutions per minute. The steam is also superheated in copper superheaters. The connecting-rod is four times the length of the crank. Each of the four cylinders has its slide-valve, and the valves are worked in pairs, by a rod to each pair, with the link-motion, having the bar-link. The frames contain the surface-condensers. The condensing water is circulated by an Appold centrifugal pump.

The two air-pumps are worked by rods direct from the steam-pistons; and they are employed also as feed-pumps for the boiler. The screw is 16 feet in diameter and 21 feet 6 inches in pitch, with two blades 3 feet 6 inches long. The annexed statement (made in April, 1862) of the results of long trials of ships on the Alexandria line, including the *Mooltan*, working with 20 lb. steam, points very strongly to the economy of fuel effected by the judicious use of the means for working expansively. (See page 345.)

This statement places in a striking light the saving to be effected by the application of known means of economising steam by expansive working. Though the engines are of 400 horse-power, and work to 1,734 indicator horse-power, their boilers have only 4,800 square feet of heating surface, or 12 square feet per nominal horse-power, and 180 square feet of firegrate surface, or 450 square foot per nominal horse-power; yet they supply the steam required for the duty. On one occasion, from noon of the 16th to noon of the 17th April, 1862, the *Mooltan* ran 300 miles, averaging 60 revolutions per minute, with steam of 24 lb. pressure per square inch, and 27½ inches of vacuum. The consumption of fuel has averaged for long periods from 2¼ lb. to 2½ lb. of coal per indicator horse-power per hour. The engines of the *Mooltan*, in short, are a great success in durability and economy.

The engines of the Peninsular and Oriental Steam Navigation Company's ship *Carnatic*, of 400 nominal horse-power, similar to those of the *Mooltan*, exerted 2,442 indicator horse-power on a trial trip, consuming less than 2 lb. of coal per indicator horse-power per hour.

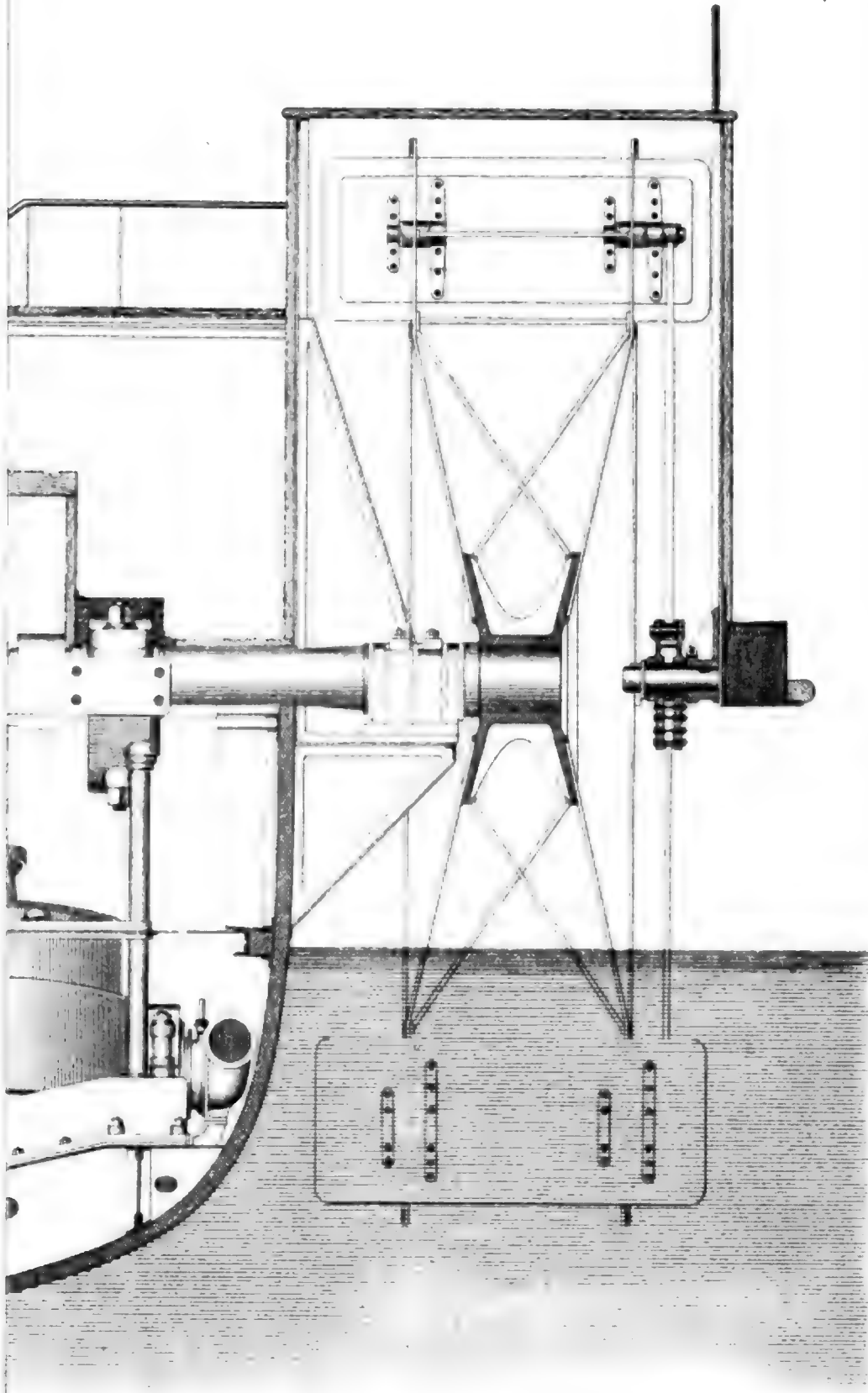
CHAPTER V.

MARINE ENGINES EXHIBITED BY MESSRS. RAVENHILL, SALKELD, AND CO.

Messrs. Ravenhill, Salkeld, & Co., London, exhibited four working models of marine engines. 1. The oscillating engines with feathering paddle-wheels are of the largest class, constructed for the City of Dublin Company's Holyhead mail-packets *Leinster* and *Connaught*, each collectively of 720 nominal horse-power. (Plates XXXII. and XXXIII.) The cylinders are 98 inches in diameter, with a stroke of 6 feet 6 inches. There is no expansion-gear, and the steam is cut off at five-eighths of the stroke. Each cylinder weighed, when finished, upwards of 20 tons, and the condensers, cast in one piece, weighed 22 tons. The air-pumps, of which there are two, are on the principle designed and patented in 1842 by the late Mr. Joseph Miller, at that time the senior partner in the firm now exhibiting. They are placed within the condensers, and stand at an angle; one on each side, worked by an inter-

NETS "LEINSTER" & "CONNAUGHT"

N.



Day & Son, Lth^{rs} to the Queen



PENINSULAR AND ORIENTAL STEAM NAVIGATION COMPANY.—PARTICULARS OF PERFORMANCE OF STEAMSHIPS.

PARTICULARS OF SHIP.					PARTICULARS OF ENGINE AND PROPELLER.										PARTICULARS OF PERFORMANCE FOR THE LAST THREE VOYAGES FROM SOUTHAMPTON AND ALEXANDRIA AND BACK.			REMARKS.
NAME OF SHIP.	Length.	Breadth	Mean Draught of Water.	Displacement.	Description of Engine.	Nominal Horse-power.	Diameter of Cylinders.	Length of Stroke.	Dia-meter of Screw.	Pitch of Screw.	Length of Screw.	Number of Blades of Screw.	Average Speed.	Average Consumption of Coal per Hour.	Average Total Consumption of Coal Out and Home.			
DELTA	324	35	16 9	2,448	Oscillating	400	72	7 0	Ft. in. Paddles. 26 0	Ft. in. ...	Ft. in. ...	No. ...	Knots per hour. 10.52	Pounds. 3,978	Tons. 1,003	...		
INDUS	241	34	18 0	1,800	Direct-action oscillating cylinders.	450	75	7 0	Paddles. 28 6	...	...	...	9.16	4,726	1,367	...		
EUXINE	222	29	13 8	1,560	Ditto	400	74½	7 0	Paddles. 28 4	...	...	...	9.54	3,673	1,016	...		
PERA	303	42	18 6	2,840	Trunk-gear	450	75 & 70¾ mean	4 0	Screw. 15 6	21 0	2 4	3	10.34	3,875	990	...		
CEYLON	306	40	18 1	2,930	Direct-acting inverted cylinders.	450	72	3 0	16 6	24 0	4 2	3	9.48	4,435	1,270	Common Screw.		
ELLORA	261	36	16 7	2,147	Direct action	300	56	2 6	16 0	19 0	2 8	3	10.22	3,651	942	Common Screw.		
MOOLTAN	348	39	19 4	3,335	Woolf's double cylinders.	400	small, 43 large, 96	3 0	16 0	21 6	3 6	2	10.64	2,574	630	During her second voyage to Alexandria and back to Southampton.		

mediate crank on the paddle-shaft. The foot and delivery-valves, and those of the air-pump buckets are of india-rubber. The feed and bilge-pumps are placed in the wing corners of the foundation-frames, and motion is given to the plungers by levers attached to the cylinders. The several bearings of the paddle-wheels are made of gun-metal. Steam is supplied from eight multitubular boilers, having forty furnaces, with an aggregate number of 4,176 tubes, or a total of $4\frac{1}{2}$ miles of tubes, with a heating surface of 16,800 square feet, or 23·3 feet per nominal horse-power. With steam of 20 lb. pressure per inch, both vessels attained an average speed at the official trial in Stokes Bay of 18 knots, or 21 statute miles, per hour, the engines making 25 to 26 revolutions per minute, and exerting 4,751 indicator horse-power. (Note.—The indicator power exerted was at the rate of a little more than 1-horse power for each flue-tube.) The paddles are feathering, and are 32 feet in diameter; and the floatboards are 12 feet long and 5 feet broad. The following additional particulars are derived from the "Practical Mechanic's Journal Record:"—"The average speed in all weathers of the two vessels on the station during the first six months of the new postal service, ending 31st March, 1861, between Holyhead and Kingstown, was 15·451 knots, or a little under eighteen statute miles, per hour. It has been found that a slimy film of organized matter (inceptive fouling) attaches to the hulls of those ships so rapidly, after coming out of dock newly coated, that within one month the speed is reduced about a mile an hour. The *Leinster* has crossed the Channel in three hours and twenty-one minutes. The extreme length of the *Leinster* and *Connaught* is 350 feet; the breadth, 35 feet; the mean draught, 12 feet 9 inches; and the area of midship immersed section, about 328 square feet. The consumption of fuel is about 31b. per indicator horse-power per hour. The average vacuum is 25 inches."

2. *Direct-acting Horizontal Screw-Engines*, with double piston-rod, and return connecting-rod, of 500 nominal horse-power, fitted by the exhibitors on board several of her Majesty's 90-gun line-of-battle ships, and representing engines of the larger class made for the British and foreign Governments (fig. 323). The cylinders are 91 inches in diameter, with a stroke of 3 feet. The slide-valves are placed vertically on the outside, and driven direct by the link-motion; and whilst advantage is taken of the arrangement—similar to that of the *Prince Consort*, already described—to bring the cylinders well towards the fore-and-aft centre-line of the ship, there is ample space left between the connecting-rod and the cylinders for getting to the glands of the stuffing-boxes of the piston-rods, and of the air-pump rods from the piston. The connecting-rod is 7 feet 6 inches long, having

five times the length of the crank. The air-pumps and the foot and delivery-valves, which are of india-rubber working on brass seats, can be easily examined and removed. The feed and bilge-pumps, in brass, are fitted with india-rubber valves, and are worked direct from the cross-heads. Revolving expansion-valves are applied. In 1845, a pair of direct-acting engines on this principle were ordered for H.M. frigate *Amphion*, of 36 guns, of 300 nominal horse-power, with 48-inch cylinders and 4-feet stroke; and it is stated that these were the first engines constructed in England on that principle. The design for these engines was the joint production of the late Joseph Miller and Count Rosen, an officer in the Swedish navy. The boilers were multitubular, having the tubes over the fire-places. These engines, also, were one of the earliest applications of the now prevailing system of arranging the machinery and the boilers below the load water-line in vessels of war. The exhibitors have since applied double piston-rod engines to upwards of forty-two vessels.

3. *A Pair of Paddle-Engines*, with inclined oscillating cylinders, in which the crank-shaft is carried by two bearings: the intermediate crank is dispensed with, and the pump is worked by an excentric on the shaft.

4. *An Engine with Surface-Condensers*, through which the condensing water is driven by means of an Appold pump driven by the engine. When the engine is at rest, the pump of course cannot be continued in action. This plan of engine, with the circulating-pumps worked by independent engines, is now being followed in the construction of the machinery of 1,000 horse-power for H.M. iron-cased frigate *Lord Clyde*.

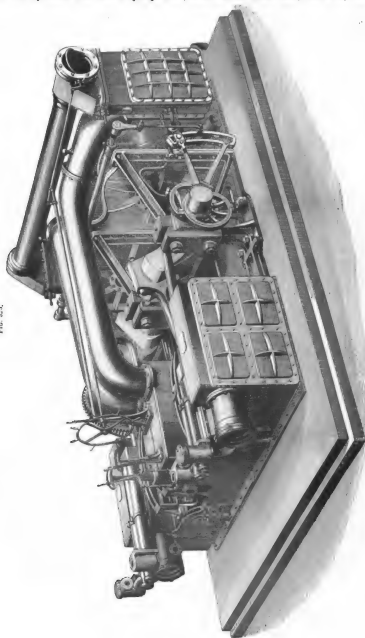
CHAPTER VI.

HORIZONTAL SCREW-ENGINES WITH TRUNKS.

Messrs. J. & G. Rennie, London, exhibited a pair of *direct-action single-trunk screw-engines*, collectively of 200 nominal horse-power, for H.M.S. *Reindeer* (figs. 324, page 348). The cylinders are $44\frac{1}{2}$ inches in diameter, which, allowing for the displacement of space by the trunk, is equivalent to a clear diameter of $41\frac{1}{2}$ inches: the stroke is 2 feet long. These belong to a type of engine peculiar to the practice of Messrs. Rennie, who have fitted many vessels, naval and mercantile, with engines of this construction, of from 60 to 400 horse-power, but they have been designed principally for low powers not exceeding 200 horse-power. The cylinders are not placed side by side, but at diagonally opposite corners, one on each side of the crank-shaft, with their respective air-pumps and condensers

beside them—each engine so far complete by itself. The cylinders and the air-pumps are worked with half trunks—trunks which are closed at the inner ends,—and they are all of

FIG. 223.

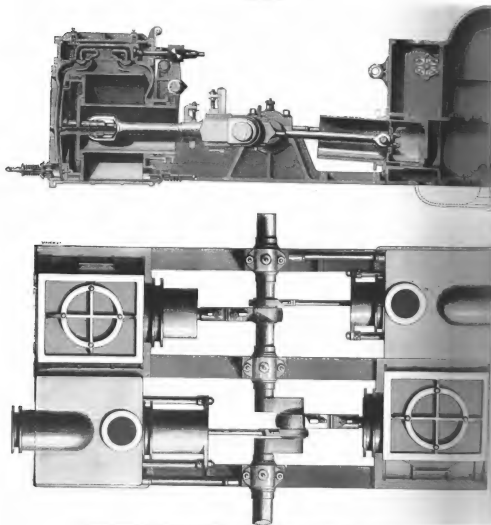


DIRECT-ACTING SCREW-ENGINES, with Double Fluctuating, of 200-horse-power, by Messrs. Russell, Stirling, & Co., London.

them coupled to the crank-shaft by connecting-rods having five times the length of the crank, joined to the bottom of the trunks. The two sides of these four-trunk engines of course accurately balance each other upon the crank-shaft. The advantage gained in these engines consists in the short and direct connection of the cylinders with their respective condensers, and the better vacuum in the cylinders—being more nearly equal to that in the condensers. The bearing of the connecting-rod at the bottom of the steam-

trunks is 6 inches in diameter, as large as it can be got in; and it can be tightened from the entrance of the trunk, whilst in motion, by means of a steel bar within the connecting-rod, abutting at one end upon the brass bearing, and at the outer end against a key and cotter set up by a screw. The air-pump trunks, or plungers, are single-acting, and are worked by a connecting-rod from each crank: they are cast of solid brass, and are fitted with hinged india-rubber valves. The feed and bilge pumps are driven by lateral fast-

FIG. 324.



DIRECT-ACTION SINGLE-TRUNK SCREW-ENGINES, of 200-horse power, by Messrs. J. & G. Renais, London (page 346).

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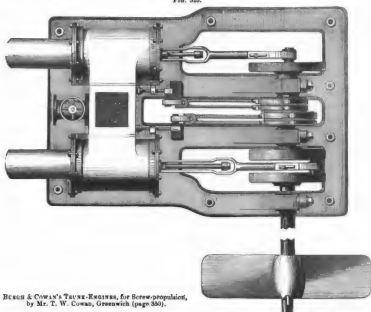
enings from the air-pump trunks. The slide-valves are double-ported, and equilibrated at the back. It is understood that Messrs. Rennie were the first who applied the balanced valve in marine engines. The valves are on the tops of the cylinders, and are worked by the link-motion by means of single shafts. A circular gridiron valve is applied close to each valve-chest.

Messrs. Rennie also constructed for exhibition, though they were not completed in time, a pair of horizontal engines, on the system of end-to-end cylinders, invented and exhibited in model by Mr. E. E. Allen, and noticed in another part of this chapter (fig. 326, page 350).

Messrs. Robert Napier & Sons, Glasgow, exhibited drawings of a pair of *direct-action horizontal screw-engines*, for H. M. S. *Hector*, collectively of 800 nominal horse-power, representing the type of engine followed by the exhibitors for the last ten or twelve years, of which they have constructed fifty pairs, aggregating upwards of 15,000 nominal horse-power (Plate XXXIV.) Of these, thirty-three pairs have been made for vessels of war in the navies of England, East India, France, and Turkey, and the remainder have been made for merchant service. The cylinders of the engines of the *Hector* are 82 inches

in diameter, with 4 feet of stroke, making 50 to 55 revolutions per minute. The propeller—Griffith's—is 20 feet in diameter, with a variable pitch of from $22\frac{1}{2}$ to $27\frac{1}{2}$ feet. The indicator-power amounted to 3,267 horse-power on the first trial trip. The chief peculiarity of these engines consists in the use of trunk air-pumps, opposite to the cylinders, as guides for the piston-rod crossheads, from which return connecting-rods of sufficient length are taken to the crank-shaft. The trunk-pumps, serving the double purpose of air-pumps and guides, work in the condensers; but, as the pumps are made large enough to clear the vibrations of the connecting-rod—being 43 inches in these engines,—the inner portion of the trunks is reduced in diameter to the required size—in this case 18 $\frac{3}{4}$ inches,—and is carried through a stuffing-box in the back of the condenser. The pumps are single-acting, with the usual foot and delivery valves; the discharge-pipe is 25 inches in diameter. The slide-valves are worked direct by the link-motion, and the starting and reversing of the engines is facilitated by the aid of two 13-inch steam-cylinders bolted to the back of the condenser, and connected by a shaft with levers to the link-motions. Both of the expansion-valves are worked in a

FIG. 325.



BECH & COWAN'S TRUNK-ENGINES, for Screw-propulsion, by Mr. T. W. COWAN, Greenwich (page 350).

simple manner by one single eccentric, and a single lever on the end of a shaft on which the valves are fixed. There are means also of disengaging the valves so as to leave them both wide open. The feed and bilge-pumps are 6 $\frac{1}{2}$ inches in diameter. The area of heating-surface is

16,204 square feet, or 20 $\frac{1}{4}$ feet per nominal horse-power: of this surface, 13,460 square feet are tube-surface. The area of fire-grate is 562 square feet, or 702 feet per nominal horse-power. The chimney is 9 feet in diameter.

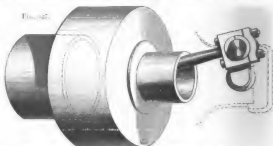
Mr. David Kirkcaldy, Glasgow, exhibited

highly elaborated and finished drawings in section of the *Persia*, with the whole of her internal fittings. This vessel is said to have been the first that crossed the Atlantic Ocean in nine days. The drawings were made by Mr. Kirkcaldy himself, who is distinguished for the extensive, trustworthy, and valuable experiments on the strength of iron and steel conducted by him for Messrs. Robert Napier & Sons.

Mr. T. W. Cowan, Greenwich, exhibited *Burgh & Cowan's anti-friction trunk-engine*, for driving screw-propellers (fig. 325). A trunk is formed upon the cylinder-cover, projecting inwards, to give space for the reciprocation of the connecting-rod, the smaller bearing of which is carried by a double piston-rod frame, projected into and guided by, and reciprocating within, the trunk. The piston is similarly made with a trunk to work over and clear the fixed trunk, and the back cylinder-cover encloses the whole with another fixed trunk. By thus truncating the cylinder, a long connecting-rod is obtained, somewhat in the manner of Mr. Maudslay's old annular engines, without incurring the frictional and cooling surface of the ordinary trunk, or reducing the working area of the piston. The engine was employed to drive one of the French pumps for supplying the fountains in the Horticultural Gardens.

Mr. Edward E. Allen, London, exhibited

cylinder is added to the back end of the main cylinder (fig. 326). The steam from the boiler is admitted into the smaller cylinder, from which it passes into and is fully expanded in the larger cylinder. The motion is taken off by a double piston-rod and return connecting-rod. The engines of the *Poonah*, constructed by Messrs. Humphrys & Tennant, are similarly designed for expansive working, with a blind trunk in the larger cylinder from which the



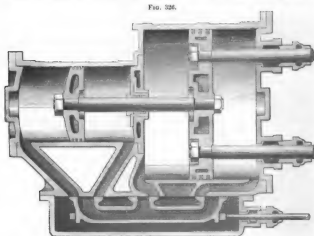
MODEL OF DOUBLE END-TO-END CYLINDER TRUNK-ENGINE, with the Pistons connected by the Trunk; by Mr. Edward E. Allen.

connecting-rod works. 2. A model of a *double end-to-end cylinder trunk-engine*, in which the pistons are connected by the trunk (fig. 327). 3. A *double single-trunk engine*, combining two single-trunk cylinders (fig. 328). The steam from the boiler is admitted into the annular space in the cylinder surrounding the trunk, where it is cut off and expanded into the outer and more

spacious end of the cylinder. The trunk works through a steam-tight packing in the middle of the cylinder (fig. 328; see, also, PORTABLE ENGINES, page 331, ante). A fixed piston may be placed in the trunk, which then becomes a moving cylinder within which the steam may be expanded. Advantages are claimed on account of the extreme shortness of the high-pressure steam-ports; and also of the reduced diameter, compared with that of the larger cylinder of the end-to-end cylinder plan, designed for expansive working.

Messrs. Knowlton

& Co., London, exhibited *Knowlton & Edwards's three-cylinder trunk-engine*, in which the three cylinders are placed at intervals of 120° round the



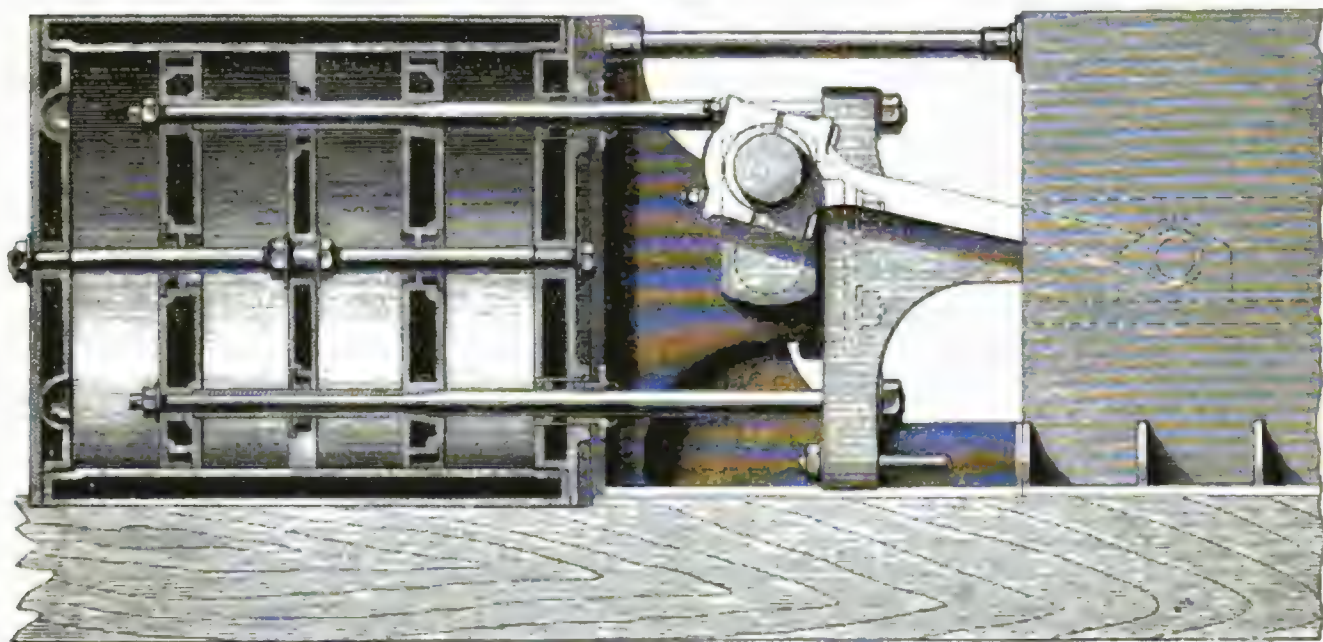
END-TO-END-CYLINDER ENGINES, with Double Piston-rods, by Mr. Edward E. Allen. (Constructed by Messrs. J. & G. Renou.)

models of two forms of *double-expansive marine engines*. 1. An *end-to-end double-cylinder engine*, with double piston-rods, in which a smaller

crank-shaft, with short connecting-rods, and spherical joints at the bottoms of the trunks. The trunks are, in fact, half-trunks, and large, and it is proposed to work the steam expansively

by exhausting it from the trunk side of the piston into the opposite side of either the same or the next piston.

FIG. 328.



DOUBLE SINGLE-TRUNK ENGINE, by Mr. Edward E. Allen, London.

CHAPTER VII.

OTHER HORIZONTAL SCREW-ENGINES.

Messrs. Caird & Co., Greenock, exhibited in Class XII. a model of a pair of *direct-action screw-engines*, with double piston-rod and return connecting-rod. The slide-valves are worked direct by the link-motion; expansion-valves, in addition, work in the same valve-chest, and are moved by segmental arcs, which are raised or lowered for the purpose of varying the cut-off. The condensers are formed with tunnels to receive the guides of the piston-rods, which are fixed within them.

Messrs. Laird Brothers, Birkenhead, exhibited a pair of *horizontal direct-acting engines*, collectively of 80 nominal horse-power, duplicates of two pairs constructed for driving the screw-propellers of H.M.S. *Jaseur* and *Newport*, of 5 guns. The cylinders are on one side, and the condenser and pumps on the other side of the crank-shaft; the cylinders are 30 inches in diameter, with 18 inches of stroke, making from 90 to 100 revolutions per minute, with 22 lb. steam. The slide-valves are vertical, on the outer sides of the cylinders, and worked direct by the link-motion, which is used for starting and reversing only. There is a cylindrical expansion-valve on each valve-chest, worked by separate gearing from the end of the crank-shaft. Balance-weights are strapped to the cranks. The crossheads work on slipper-guides. Of the three longitudinal pieces of the frame carrying the crank-shaft, the centre-piece alone unites the opposite sides of the engines; the two outer

pieces are stopped short under the shaft, and are solely intended to unite the shaft plummer-blocks to the cylinders: hence the engine has no rigidity within itself, and must depend upon the foundation to which it is bolted. The air-pumps are worked direct from the pistons. The two sections of the engine are not balanced upon the crank-shaft, the cylinders being set back sufficiently to get in a connecting-rod 3 feet long, or four times the crank, and the condensers are brought near to the shaft.

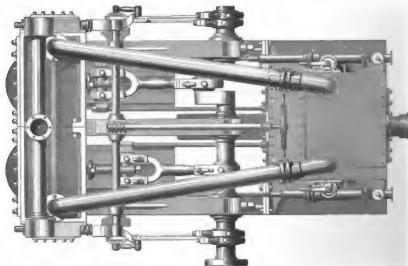
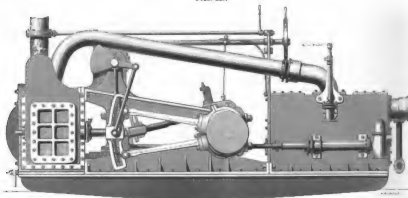
Mr. John Key, Kirkcaldy, exhibited a pair of *horizontal direct-acting engines*, collectively of 80 nominal horse-power, for driving a screw-propeller (figs. 329). The engine is arranged in the usual manner—the cylinders opposite the condenser and air-pumps, and the crank-shaft between. To save space, the stuffing-box is projected into the cylinder, the piston being suitably formed; but there is no attempt at balancing the masses, the connecting-rods being of good length, and the cylinders considerably further from the shaft than the condensers. The slide-valves are on edge, and worked by a link-motion, reversed by means of a worm-wheel on the reversing shaft, turned by a screw of quick pitch on the end of the hand-wheel rod. The air-pumps and feed-pumps are worked direct from the crossheads; and these work in slipper-guides. The pump-valves are not readily accessible. The crank-shaft is carried by three cast-iron triangular A-frames bolted to the cylinders, and the whole engines are bolted down to strong cast-iron foundation-plates. The clutch-pins for coupling the crank-shaft to the propeller-shaft are fixed on the fast disc on the crank-shaft.

Messrs. A. & J. Inglis, Glasgow, exhibited

drawings of a pair of *direct-action screw-engines*, collectively of 200 nominal horse-power, for H.M.S. *Chanticleer*. They are constructed after the horizontal system of Messrs. Humphrys & Tennant, with a short connecting-rod, which was adopted as the type; but there is no passage-way across behind the crank-shaft. The

feed and bilge-pumps have between them one brass plunger or ram in a barrel, fitting metal to metal, without packing; it cannot be packed, which is objectionable. A screw shut-off fan valve is applied next the side of the ship for the discharge of the bilge-water, but it is not self-acting.

FIGS. 329.



DIRECT-ACTION SCREW-ENGINES, of 80 horse-power, by Mr. John Key, Kirkcaldy (page 351).

CHAPTER VIII.

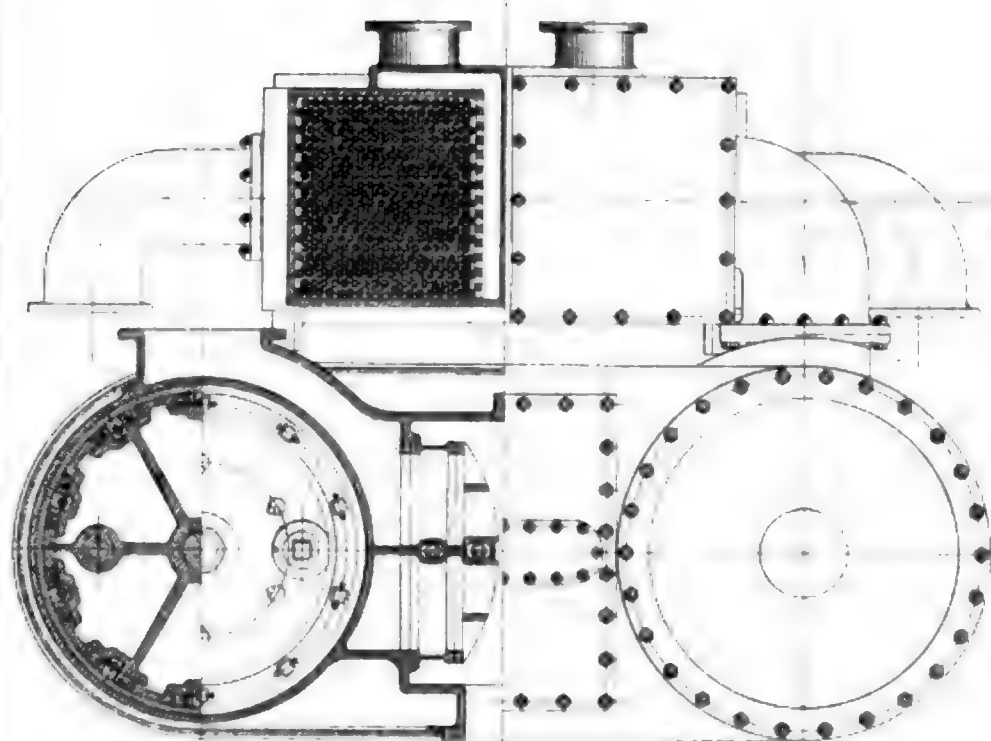
INVERTED-CYLINDER SCREW-ENGINES.

Messrs. Thomas Richardson & Sons, Hartlepool, exhibited a model of a pair of *inverted-*

cylinder screw-engines, collectively of 160 horse-power, for merchant vessels, fitted on board the transport *La Charente*, of the Imperial French Navy, and the *Tynemouth*, the property of Mr. W. S. Lindsay, M.P. The cylinders are

BUCKET COMPANY'S SHIP "AUCKLAND"

P L A N



W. A. L. L. C. - the engine is a 100

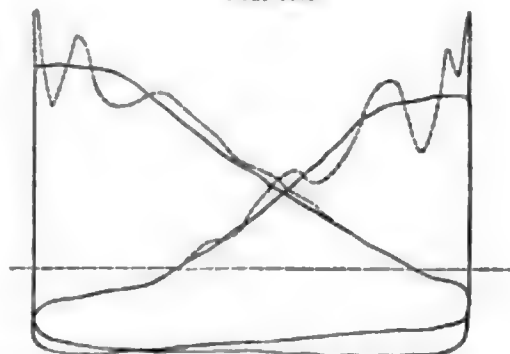
inches in diameter, with a stroke of 2 feet 6 inches, making 70 revolutions per minute, indicating 638 horse-power. The cylinders are steam-jacketed, and have double piston-rods; connecting-rods also are double, formed of parallel rods, which are simply screwed through the brasses, but should have been tapered to them. The slide-valves are double each cylinder-face, with very short steam-stems. They are enclosed, for the two cylinders, in one box between the cylinders—convenient to make, but not to examine or repair. The valves are worked expansively by a link-motion, reversed by a screw-and-nut motion. The expansion-link is double, or is properly a pair of links, between which the ends of the excentric-rods are pinned. The crank of the shaft is overhung on an inside bearing, which is liable, thus only half-supported, to get overheated. The bearings are entirely of white metal, without any gun-metal frame to support them. There is an insecurity in this disposition, should the bearings get overheated, the metal would vanish altogether. The air-pumps are placed at the side in an upright position—which is good,—and worked by means of levers in the crossheads of the steam-cylinders. There is a feed-heating apparatus between the cylinders and the condenser, where the feed-water is heated on its way from the pumps to the boilers. The boilers are multitubular, with a superheating apparatus. The fuel consumed, it is stated, never exceeds 112 lb. for every 10 nominal horse-power, or 40 indicator horse-power, per hour; or 2.8 lb. of coal per indicator horse-power per hour.

Messrs. Robert Morrison & Co., Newcastle-on-Tyne, exhibited a pair of *inverted-cylinder screw-engines*, of 30 nominal horse-power, occupying a space of only $5\frac{1}{2}$ by 4 feet, with surface-condensers. The cylinders are 18 inches in diameter, and have 18 inches stroke; and between them, with the central valve-chest, which is completely surrounded by a steam-jacket. The valve-chest holds the main slide-valves, with two variable expansion-valves, in Meyer's system, on their backs. Each valve is worked by a single excentric—four loose excentrics for four valves; the two main excentrics are loose on the shaft, and connected together, and retained in their proper positions for going ahead or astern, by stops bolted to the shaft. The two expansion-excentrics are also joined together, and are loose on the connecting-sleeve between the main excentrics, and provided with proper stops. The expansion is regulated by a hand-wheel on the top of the engines. A small auxiliary valve with steam-ways is applied for the purpose of starting and reversing each engine. An air-pump on one side, and a cold-water pump on the other, both single-acting, are fixed beside the valve-gear, and worked by rods direct from the pistons. The propriety of working the pumps by single action is questionable for high-

speed working. The cylinders are supported by three hollow castings—a broad casting at the back, and two standards at the front, one to each cylinder, bolted to the base-plate. The back casting is partly fitted as a surface-condenser, with tubes, which are accessible by a doorway behind. The remainder of the back casting communicates with the base-plate and the front standards, which together form a hot-well to hold the distilled water delivered from the air-pump. The engines are designed to work with steam of 60 lb. pressure per inch, and to expand the steam from six to eight times.

The accompanying illustrations (Plates XXXV. and XXXVI.) represent the inverted-cylinder engines, similar to those exhibited by Messrs. Morrison & Co., of the screw-steamer *Auckland*, belonging to the Intercolonial Royal Mail Steam-packet Company. The cylinders are 45 inches in diameter, with a stroke of 2 feet 6 inches. They have indicated 619 horse-power with steam

FIG. 330.



INDICATOR-DIAGRAMS, taken from one of the engines of the *Auckland*, manufactured by Messrs. Robert Morrison & Co., Newcastle-on-Tyne.

of 30 lb. per square inch, cutting off at one-third, and making 63 revolutions per minute (fig. 330).

Messrs. Tod & McGregor, Glasgow, exhibited a pair of *direct-acting inverted-cylinder screw-engines*, of 60 nominal horse-power, with surface condensers, the same as the engines of the merchant ship *Naughty*, trading between the ports of Havre and Santandar. The cylinders are 30 inches in diameter, with a 22-inch stroke, bolted together, with a single valve-chest between them. There are two main valves and two expansion-valves within the valve-chest, worked by six excentrics on the crank-shaft—two pairs for working the main valves with the link-motion, fitted with bar-links, to start and reverse, and the remaining two to work the expansion-valves. The chief feature of these engines consists in the disposition of the condenser (Sewell's condenser), which forms a part of the back frame. It contains 734 tubes, placed horizontally, $\frac{3}{4}$ inch outside diameter, and 6 feet long. The condensing water passes through the tubes, in a contrary direction to the steam, making a condensing surface amounting to 14 square feet per nominal horse-power—about five-eighths of the heating-surface of the

boilers. The tubes are packed at each end with a large perforated sheet of india-rubber about $\frac{1}{2}$ inch thick, through which they project, and are secured by a perforated brass plate, which is removable, and gives free access for cleaning the tubes inside and outside. The india-rubber does not rub on the tubes as they expand and contract, but yields with them—hence its durability; and it is kept tight by the pressure of the condensing water. The tubes in this class of condenser are placed at from $\frac{1}{16}$ to $\frac{3}{8}$ inch apart. The air-pump and cold-water-pump are each 11 inches in diameter, with 11 inches of stroke, and double-acting. They are placed horizontally, one on each side of the crank-shaft, and are worked by excentrics with very compact parallel motions. One of the excentrics works the feed and bilge-pumps in addition. The rubbing surfaces appear to be scarcely sufficient for working without undue wear; for there must be considerable friction, involving considerable lubrication. With steam of from 19 to 22 lb. pressure per inch, cutting off at half-stroke, making 81 revolutions per minute, a vacuum of from 27 to 28 $\frac{1}{2}$ inches was maintained, the temperature of the sea being 60° Fahrenheit; that of the discharge-water, from 90° to 100°; and that of the feed-water, from 2° to 9° higher. The density of the water in the boiler was 6 oz. per gallon. The crosshead is forged solid upon the piston-rod, and thus saves a little in the depth. Balance weights are applied to the cranks, to which they are dovetailed.

CHAPTER IX.

OBLIQUE ENGINES.

Messrs. Randolph, Elder, & Co., Glasgow, exhibited drawings of a pair of *direct-acting oblique engines* for H.M. frigate *Constance*, collectively of 500 nominal horse-power, worked expansively by superheated steam of high pressure. The engines are inclined towards the crank-shaft at an angle of 120° with each other. Each engine is composed of three cylinders, into the middle one of which the steam from the boiler is admitted, from which it is expanded into the two outer cylinders. The cranks of each engine are directly opposed to each other, so that the steam is exhausted from the middle cylinder into the neighbouring ends of the others through the shortest passages that can be made. The air-pumps are cast in a piece with the condensers under the cylinders. The cylinders are completely steam-jacketed, and are worked with steam of 35 lb. pressure per square inch, and intended to make from 40 to 45 revolutions per minute. The high-pressure or middle cylinders are 60 inches in diameter, with 3 feet 3 inches stroke; the steam is cut off at half stroke by a gridiron slide-valve, and

is expanded into the two outer and larger cylinders, 78 inches in diameter, and thence exhausted by means of double-ported slide-valves in casings between the middle and outer cylinders. Each set of three cylinders are bolted together and also to the condenser, which is a casting forming the bed-frame of the engine; and, on account of their opposite moments neutralising each other, the transverse strain of the steam-pressure in the cylinders the crank-shaft is very much reduced, as is the tendency to shake the ship. The face condensers are on Sewell's system, also noticed in the engines of Messrs. Tod & McGregor, but they may also be worked with injection-condensers. The air-pumps, circulating pumps, and feed and bilge-pumps are worked by rocking-shafts driven from the ends of piston-rods of the aft low-pressure cylinders. The six slide-valves are worked by two excentrics on the crank-shaft, on Mr. Edgworth's system, so arranged that when in motion the engine can be made to reverse itself within a turn, by causing the excentric gear to overtake it. The engines are started by the aid of a diagonal auxiliary engine, having two 12-inch cylinders with 12 inches of stroke. The engine can be controlled by one man on the standing platform. The steam is supplied by four tubular boilers, having an aggregate fire-grate area of 288 square feet, and provided with tubular superheaters. The average consumption of steam in similar engines varies from 2 lb. to 2 $\frac{1}{2}$ lb. per indicator horse-power per hour. The aggregate weight of the engines, shafting, and propeller is 280 tons, and of the boilers, chimney, and bunker, 160 tons. The details of these engines have been worked out in a thoroughly practical manner, easily accessible, and easily inspected while at work.

CHAPTER X.

FOREIGN MARINE ENGINES.

The "Société Nouvelle des Forges et Chaudières de la Méditerranée," Paris, exhibits a pair of *direct-action screw-engines*, collectively of 400 nominal horse-power, on a type which they have practised for nine years, and of which thirty-one engines have been applied to the ships of the "Messageries Impériales" and to ships of the French navy and others. The cylinders are 4 feet 11 inches in diameter with 3 feet 7 inches of stroke. The screw is cast iron, with four blades 17 feet in diameter. They have double piston-rods with return connecting-rods, for which the guides are placed in a tunnel through the condensers, as in Messrs. Caird & Co.'s engine. The guide-bars are formed with hollow curved surfaces, one above and one below the crosshead, probably so formed

to have space laterally. The slide-valves—the old **D** slides—are placed on the tops of the cylinders, and are worked from a transverse shaft directly over the crank-shaft, and driven by means of a pair of spur-wheels. Expansion-valves are also applied, worked from two eccentrics on this shaft, the positions of which are adjustable in advance or in retreat, by means of wheelwork, so as to cut off the steam at from 10 to 60 per cent. of the stroke. There is a square coupling for the screw-shaft; the thrust is taken next the screw, but the thrust-bearing would be better protected if placed at the coupling in the usual manner. Though the engines stand high, they are compact on the floor; they manifest also great attention to details. There are plenty of bolts in the cylinder-covers; the pump-valves are accessible, and the covers of the valves are put on with metallic points, having easing screws to slack them off when the nuts are removed. The workmanship is second-rate, but there is no parsimony of work, and the engines, taken as a whole, are complicated.

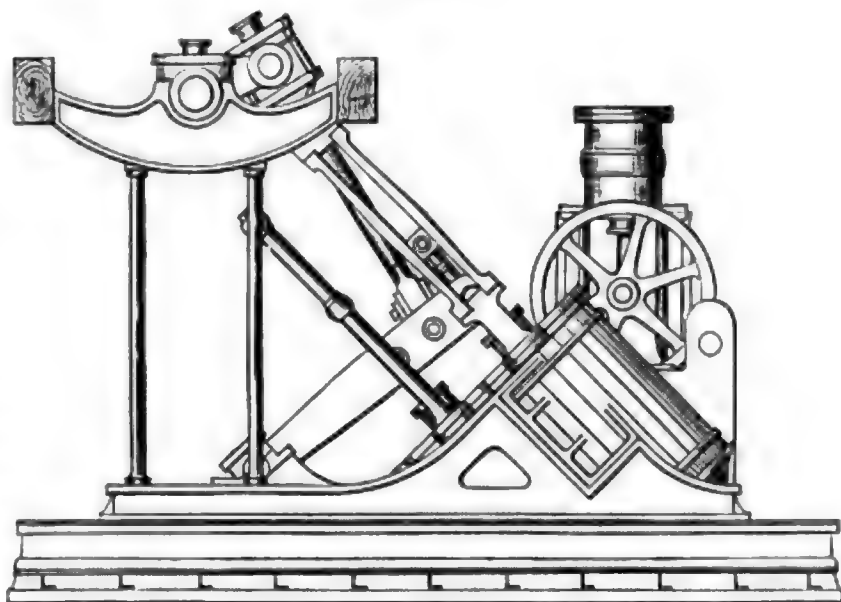
M. E. Nillus, Havre, exhibited a pair of *direct-acting screw-engines*, with double piston-rod and return connecting-rod, collectively of 40 nominal horse-power. The cylinders are $23\frac{3}{4}$ inches in diameter, and have 18 inches stroke, making 100 revolutions per minute. The arrangement is like that of Messrs. Robert Napier & Sons, having a trunk air-pump, from which the connecting-rod is worked, but deprived of the extended through bearing at the back of the trunk. The reversing gear is worked by rack and pinion on friction-rollers, and is needlessly complicated with double-sided or "spider" links, rocking-shafts, and return valve-rods. There is no ready means of access to the feed-pump valves. The workmanship is good.

M. A. W. Frestadius, Bergsund, Stockholm, exhibited a *horizontal direct-action screw-engine*, with a compound cylinder, for the gunboats of the Swedish navy, of 60 nominal horse-power. The smaller cylinder, $13\frac{1}{2}$ inches in diameter, is placed within the larger, which is annular, and 30 inches in diameter, with 24 inches stroke, making 120 revolutions per minute. One piston-rod from the inner piston, and two from the outer, are united in a crosshead, beyond which the two outer rods are prolonged over and across the shaft, and terminated by a second crosshead, from which an inverted connecting-rod works the crank. The cylinders are fitted with a double-ported slide-valve worked by a

single eccentric, which is movable for reversing across the shaft, in an oblique slot, by means of a cylindrical rack and pinion. The condenser is cast within, and forms part of, one side of the base. As the centre lines of the crank-shaft and the cylinders are in different horizontal planes, the one-sided action of the connecting-rod will act unfavourably, in shaking the guide-blocks at the dead points.

M. M. Escher, Wyss, & Co., Zurich, exhibited a pair of *compound-cylinder paddle-engines*, for lake and for shallow-river navigation, of 30 nominal horse-power (fig. 331). They are designed to work with fresh water, and can be worked, if required, non-condensing. The engines are direct-action and inclined, so as to have a good stroke and a long connecting-rod,

FIG. 331.



COMPOUND-CYLINDER PADDLE COLLECTIVE ENGINES of 60 horse-power, for Shallow Navigation, by Messrs. Escher, Wyss, & Co., Zurich.

without raising the shaft too high. The power of each pair of cylinders, worked on Woolf's system, is delivered to one end of a rocking lever, from the same end of which the connecting-rod is taken to the shaft. The small or high-pressure cylinders are 15 inches in diameter, with $24\frac{3}{8}$ inches stroke; the larger cylinders are $21\frac{1}{2}$ inches in diameter, with 39 inches stroke. The cranks are 16 inches long, with 32 inches of throw. The cylinders are completely jacketed with steam; they are worked by one slide-valve, moved and reversed by the link-motion, by which also the degree of expansion may be varied, but only to a small extent. The capacity of the larger cylinder is three times that of the smaller; and when the steam is cut off at 73 per cent. of the stroke, it is expanded $4\frac{1}{2}$ times. The engines can be worked up to 180 horse-power by the indicator, with 75 lb. steam in the boiler, and making 40 revolutions per minute, with a consumption of $2\frac{1}{4}$ lb. of coal per horse-power per hour, propelling a vessel 165 feet long, $16\frac{1}{2}$

feet broad, with $3\frac{1}{4}$ feet draught of water, and 110 tons displacement, at a speed of 15 miles per hour. There are a condenser and an air-pump placed upright, worked by a separate steam-cylinder, making 60 strokes per minute when the engine is doing 40, from which the exhaust steam is discharged into the chimney, to increase the draught, or is condensed when not required for draught. A motion is taken from it to work the feed-pump; but the bilge-pump is worked from the engine.

CHAPTER XI.

CONCLUDING REMARKS ON THE MARINE ENGINES.

The worth of the facilities afforded by the use of superior tools in the manufacture of marine engines was strikingly apparent in the sterling solidity, accuracy, and finish of workmanship that was exhibited,—in many instances, absolutely as fine as that of a chronometer. The improvement of taste in outline was likewise apparent, encouraged probably by the geometrical simplicity of form suggested, and to a considerable extent enforced, with the extensive use of machine-tools. Machinery, dealing with direct strains, is best formed by straight lines and circles; and it has happily been emancipated, to a great extent at least, from the pitiable architectural forms and mouldings repugnant to the nature of cast iron. The engine-work of Messrs. John Penn & Son was unsurpassable in delicate proportions and refinement of workmanship. In the engines of Messrs. Maudslay, Sons, & Field, the utmost degree of solidity and security of workmanship and strength was to be remarked. Those of Messrs. Humphrys & Tennant were characterized by simplicity in outline and construction, and the total absence of ornament or of superfluity of any kind, with a close and economical application of means for the purposes to be effected. These engines, moreover—of first-rate workmanship,—bear the impress of originality and independence of treatment, with a resolution to remove the difficulties and surmount the obstacles which plentifully await the originators of new styles. The exhibited works of those three firms would alone have sufficed to secure the position of the British marine engineers at the head of their profession.

Of the systems adopted for compressing the bulk of the horizontal marine engine, the methods of the trunk and the return connecting-rod are the most common. The trunk is applied in various ways, but the double or through trunk-system of Messrs. Penn gives the best and most consistent form of trunk-engine;—the trunk, being carried at both ends through the cylinder covers, is amply supported for resisting the thrusts of the connecting-rod, or for guiding the piston, whilst it affords a great length of connect-

ing-rod, and gives the greatest facility compatible with the use of a trunk, for attaching the connecting-rod, and inspecting the bearings. The trunk, moreover, supersedes the ordinary mechanism of crossheads, guides, and piston-rod, and so materially simplifies the engine.

The four-trunk engine exhibited by Messrs. Rennie, whilst it possesses the advantage of a short and direct passage from the cylinder to the condenser, which are placed together—so facilitating the completion of a vacuum in the cylinder,—open to the objection that applies to blind or half-trunks, that the bearings of the four connecting rods from the cylinders and the air-pumps are placed in positions, at the bottom of the trunks, where they are not conveniently accessible for inspection and handling. The steam-pistons, also, are directly subjected to the thrust of the connecting-rods, which is transmitted to the working surface of the cylinders; thus the cylinders are exposed to wear on the lower side, and the trunks to irregular wear in the stuffing-boxes. The air-pump trunks are open to the same objections, though it appears that by making the neck-boxes of great depth, the wear may not be objectionable. Again, whilst the condensing arrangements are simplified, the steam-pipes, as well as the standing valve-gear, are a little more complicated; the parting of the plummer-blocks, also, is required to be made horizontally, though a vertical parting is better for dealing with the strain of the engine, and the one generally adopted. The general effect of the disposition of these engines, is to make them a little more compact crosswise—having but the united width of a cylinder and its condenser; but a little greater in length, as space has to be provided for a double length of cylinder with their connecting-rods.

On the contrary, the half-trunk air-pumps of Messrs. Napier's engines, which have ordinary cylinders, receive, through a couple of rods, the motion of the pistons; and being substantially supported in bearings through the back of the condenser, they afford a steady and durable fulcrum for the return connecting-rod.

Messrs. Burgh & Cowan's trunk-engine, an untried plan, obviates the ordinary objections to trunks—of extensive frictional and cooling surfaces, and displacement of working space in the cylinder; but the guides are inaccessible, as being projected into the cylinders without internal support, they cannot be sufficiently sustained, except, possibly, in engines of very small dimensions.

The omission of the back guide for the half-trunk pumps of M. Nilus's engines, which are otherwise like Messrs. Napier's, is a fatal omission, the pumps being thus unfitted to take the thrust of the steam connecting-rods.

The arrangement of large and small cylinders placed end to end, for marine engines, was first suggested by Mr. Edward E. Allen, and patented by him in 1855. He preferred the horizontal

arrangement, as constructed by Messrs. Rennie, to the vertical arrangement; and his method of uniting the pistons solidly by a trunk, through which the thrust of the connecting-rod is taken up by both pistons, and with which a long connecting-rod may be obtained, appears to be preferable to the mode of connection by a piston-rod and a half truck.

The method of the return connecting-rod, in conjunction with the double piston-rod, avoids the objectionable features of the trunk system—the large frictional and cooling surfaces of the trunk, and the concealment of the connecting-rod ends—though it involves the use of considerably more mechanism; but by suitable dispositions, every important wearing part may be made freely accessible, and brought under direct observation. The proximity of the crank-shaft to the cylinders, moreover, admits of a stiff, compact, and solid connection between the bearings of the shaft and the cylinders, which is preferable to the open triangular framework of other engines; whilst by the spread of the condensers, direct eduction-pipes are permissible below the level of the cylinders, without interfering with the working parts. The double-piston-rod system has been worked out in the best manner by Messrs. Maudslay, Sons, & Field.

The double-piston-rod engines of Messrs. Caird & Co. have a fine appearance, and are evidently the work of able and experienced constructors—spacious, massive, and easy; but they occupy a large horizontal surface, and the concealment of the guides within the condenser is objectionable. The engines of the Forges et Chantiers are open to the same objection.

M. Frestadius's compound engine, with inverted piston-rod, was the greatest novelty in marine engines, though it is not likely to be imitated. The annular expansion-cylinder, and the difference of the planes of the centre lines of the crank-shaft and the cylinders, are objectionable features.

The third type of marine engine, specially designed with a view to compactness—by simply shortening the connecting-rod—is most ably represented by the engines of Messrs. Humphrys & Tennant. The terms “short” and “long,” applied to a connecting-rod, are comparative; nevertheless, there is a right and there is a wrong in the length of the rod. By general concurrence, in steam-engine practice—or wherever else a connecting-rod is employed for the transmission of force—it is not by preference made shorter than five times the length of the crank. In the engine of Messrs. Humphrys & Tennant, therefore, having connecting-rods only three and a half times the length of the crank, careful provision, as may reasonably be expected, is made for the extra strain and thrust of the connecting-rod. In the first place, the crank-shaft is large: it is $12\frac{1}{2}$ inches in diameter for 400-horse-power engines. Messrs. Penn's is $13\frac{1}{2}$ inches, for

600-horse-power engines. Then the bearings of the shaft are 25 inches long, or twice the diameter, the outer bearings occupying the whole space from the crank to the excentrics. Accordingly, if a comparison be made between the capacity of the cylinders,—the area of the piston multiplied by the stroke,—and the area of crank-shaft bearing opposed to the strain, reckoned as the product of the diameter by the gross length of bearing surface, it will appear that Mr. Humphrys provides the greatest proportional area of bearing in the ratio of 2.05 to 2.02 by Messrs. Penn, and to 1.00 by Messrs. Maudslay & Co. Again, the sliding surface of the slipper on the guide is 360 square inches, or 1 square inch for about 9 inches of piston area in Mr. Humphrys' engine; whilst Messrs. Maudslay & Co. allow only 405 square inches for a piston of more than double the surface, or 1 square inch for 16 inches of piston area. These are striking comparisons, and assuming that the respective engineers have matured the proportions of their engines, it would appear that the short connecting-rod materially increases the working strain of the machinery, compared with the longer rod. The plan of the separate wearing-piece provided by Mr. Humphrys under the slipper, for ready renewal, is a useful provision for keeping the piston-rod in line, which, being short and rigid, the more readily binds in the stuffing-box when it diverges from the central line. With regard to the power absorbed in opposing the extra friction of the short connecting-rod, relatively to that of a longer rod, it may easily be shown by calculation, in terms of the known frictional resistance of rubbing bodies, to be but a small fraction of power, so long as the working surfaces remain true; but contingent deviations from the true surfaces, if neglected, would involve a very different calculation. The flexibility of the trunk-engine, and, to a great extent, the elasticity of the double-piston-rod system, obviate the chances of the bad effects of this sort of wear. The largest engines constructed on their peculiar type by Messrs. Humphrys & Tennant, are those of 500 collective horse-power, for H.M.S. *Prince Albert*, and the 600-horse-power engines for H.M.S. *Liverpool*.

The adoption by Messrs. Humphrys & Tennant of the single condenser with the central eduction-pipe, common to both engines, whilst it simplifies the machine, controverts the principle of establishing two independent engines, which, though it may be of less moment for small powers, is held by their Lordships of the Admiralty to be necessary for high powers of engines, and is followed in the engines of other exhibitors.

The inverted-cylinder engines are favourite engines for merchant service, as they are simple, compact, and accessible. The dribbling of tallow and oil from the stuffing-boxes and other parts is, however, a nuisance. The upright engines of Messrs. Morrison & Co. are

probably the most simply arranged; but the system of loose excentrics for working the valves, as well as the single action of the water and air pumps, which are vertical, and are worked by direct action for the sake of simplicity, are not to be commended in an engine that works at a high speed; though there is this advantage in the single action of the pumps, downwards, that it aids in counterbalancing the piston and its connections during their descent.

Messrs. Tod & McGregor, on the contrary, verging towards the opposite extreme, have, for the sake of double action, placed their pumps horizontally, and they work them by an involved excentric-motion from the crank-shaft. But the surface condenser is a superior feature of their engine, with its compact distribution of the tubes, and their free accessibility for examination, cleaning, and repair.

Messrs. Humphrys & Tennant's upright engines for the *Mooltan* are chiefly to be remarked for their compound cylinders, and the notably economical results of their appliances for expansive working, in fuel, by the instrumentality of the simple slide-valve and link-motion, without any additional expansion-valve.

The magnificent oscillating engines represented in model by Messrs. Ravenhill, Salkeld, & Co., are certainly amongst the best proportioned and the best executed engines that are to be seen. They are, nevertheless, open to the objection, unhappily incidental to all oscillating engines, working the air-pumps from an intermediate crank in the shaft. Three out of the four large Holyhead steamers, worked by the above, and two similarly constructed oscillating engines, have broken their intermediate cranks—one of them twice over. The breaking strain does not, of course, arise from the mere working of the air-pumps, but from the strain of the paddles, which overmatches the essentially weak form of the cranked shaft.

The inclined paddle-engines of Messrs. Escher, Wyss, & Co. are effectively designed for their purpose, and in execution may be freely compared with English engines. The separation of the air-pump from the engine, to be worked independently, is a good and serviceable plan, and it is worthy of general adoption in larger paddle-engines. There are only two ways of working the air-pumps without cranking the intermediate shaft—by an excentric on the shaft, or by working them altogether apart by an independent engine.

With the increasing high speeds of marine screw-engines, there follows the necessity for balancing the reciprocating and revolving parts,—a necessity long since experienced in the practice of locomotive engines, and now amply provided for in the balance-weights which find their convenient location in the driving-wheels. The marine engine does not offer the same degree of facility for the placing of balance-weights, and there is nothing in it to correspond

with the wheel of a locomotive, except the wheels of paddle-engines. Mr. John Bourne, in his patent of 1853, pointed out the usefulness of balance-weights in high-speed screw-engines; and Messrs. John Penn & Sons first applied them, as exemplified in the engines which they exhibited, where they applied them directly behind the cranks—the best position for the purpose. But these are calculated only for the revolving masses, leaving the reciprocating parts unbalanced. Messrs. Maudslay, Sons, & Field apply the counterweight within the large worm-wheel on the outer end of the crank-shaft, which is a position sufficiently effective for the immediate object in view—the obviating of any vibratory action upon the ship herself. The same constructors, for the same purpose, designed the three-cylinder engines of the *Octavia*, which perfectly fulfil the objects of balanced action and regular motion. Nevertheless, it is desirable that the method of balancing engines by counterweighting the reciprocating masses, in addition to the revolving masses, should be thoroughly worked out in ordinary marine engines, as it has already been done in locomotive engines (see page 2, *ante*), in which it was first applied in this country by the Author.

The days of economy of fuel, and of compound marine engines, have begun: the theory and practice of steam-jackets are now thoroughly understood; and it is established that economy of fuel is vainly sought in expansive working of steam, without the use of means for preventing the condensation of the steam within the cylinders. For the attainment of this object, the complete envelopment of the cylinders in steam-jackets, supplied direct from the boilers, has been proved to be sufficient. Messrs. John Penn & Son applied steam-jackets to the 500-horse-power screw-engines of H.M.S. *Windsor Castle*, in 1858, which appears to have been the earliest application of them to screw-engines. Messrs. Maudslay, Sons, & Field applied them three or four years ago to the screw-engines of the *Gibraltar*. But the jacket was applied to the cylinders of paddle-engines upwards of twenty-five years ago. The use of superheating apparatus, so far as to dry the steam delivered from the boilers previously to its passing into the cylinders, is also a practice of acknowledged utility in promoting economy of fuel. But, two questions remain to be decided,—Whether the best results are to be had from two or from more than two cylinders? and, Whether the steam should be surcharged with heat? Surcharged steam is void of the quality of lubrication, and it carbonises any ordinary lubricant delivered into the cylinders, to the detriment of the working surfaces. According to the best experience at the present time, the combined use of the steam-jacket outside, and dried but not superheated steam inside, the cylinders affords the most satisfactory result.

For working steam expansively, there are various forms of expansion-gear, which may be reduced to two classes. The first of these, and the simplest, is the link-motion, working a single valve with two eccentrics—which is employed in all the operations of starting, reversing, and expansive working. It is identified with the name of Stephenson, and has become, after many attempts to supersede it, universally adopted for locomotive engines, with a few trifling exceptions. In the second class, a distinct expansion-valve, worked by additional gearing, is employed, in addition to the ordinary slide-valve worked as before by the link-motion, for starting and reversing only. The link-motion, notwithstanding all the defects, real and imaginary, with which it has been charged, very favourably fulfils the purpose of the expansive working of steam, without the aid of an additional valve. The use of the additional valve for expansive working, nevertheless, obviates the practical objection to the link, that it prematurely closes the communication of the cylinder with the condenser during the return of the piston—an objection frequently exaggerated; and also that other objection of very little practical importance—the wiredrawing of the steam while it flows into the cylinder. The main benefit conferred by the use of an additional valve for expansive working—the link-motion being retained for starting and reversing—consists in the facility it gives for constantly working the link solidly and steadily in full gear with the valve-spindle—a benefit which has been fully accepted

in several engines—those, for example, of Messrs. Maudslay, Sons, & Field. For the engines of the *Prince Consort*, with their short eccentric-rods pinned to the back of the short, open link, it is particularly adapted; because, with that combination, the angular play of the link, and the slip of the block in it, would be very considerable, if they were directly employed for variable expansive-working—considerably more so than with the long link and eccentric-rods of Messrs. Penn & Son, or those of Messrs. Humphrys & Tennant; in the latter of which, moreover, the rods are pinned centrally to the ends of the link, by which the plunging of the link is diminished. These engines, accordingly, are expansively worked entirely by the link; and it is understood that Messrs. Penn's engines, also, notwithstanding the presence of the separate expansion-gear, are for the most part worked by the link.

The principle of the independent air-pump, driven apart from the engines, exhibited by Messrs. Escher, Wyss, & Co., would be likely to prove of service if adopted in English practice. High-speed engines, untrammelled by the air-pump, could be driven at the best speed for the work to be done, whilst the pump, free from the engine, would be worked at its proper speed by its own steam-cylinder.

The application of special steam-gear for starting the engines—as, for example, the starting-valves applied to the cylinders by Messrs. John Penn & Son—is a commendable adjunct for large marine engines.

SECTION III.

PIECES AND FITTINGS OF STEAM-ENGINES AND BOILERS.

CHAPTER I.

FORGINGS.

The separate pieces exhibited afforded ready facilities for minute examination; and they proved in themselves, as pieces of workmanship, the decided progress that has been made in the means and facilities of construction, by the invention of special tools, and their extensive and multifarious employment.

The articles made of Bessemer steel generally surpassed in magnitude those which had been constructed of steel manufactured on the ordinary system. The method of manufacture of Bessemer steel, by injecting streams of air into a molten mass of pig-iron, is so generally known, that it is scarcely necessary to describe it minutely. The tensile strength of the metal, as proved by Colonel Eardley Wilmot, R.A., at Woolwich Arsenal, varied from 150,000 to 160,900 lb. per square inch.

M. F. Krupp, Essen, exhibited a most remarkable collection of works in cast-steel, which, like all the other forgings of this maker, are melted in crucibles, and poured in solid ingots. The following subjects are particularized:—
1. *A cylindrical ingot*, in the simple cast state, 44 inches in diameter, and 8 feet long, weighing 20 tons. This ingot was broken across at the middle in the cold state, after having been cut in at each side by a saw, under the largest hammer in the works, the falling weight of which is 50 tons. The fractures thus produced serve to show that the manufacture of the largest pieces is sound, and that the rough ingots are free from honeycombs or faults.
2. *A square ingot of cast-steel*, of 4 tons weight, one half of which was in the normal state, and the other half was forged; it was broken longitudinally, and showed the fineness of grain, soundness and toughness of the metal in either condition.
3. *A forged ingot of cast steel*, 15 tons weight, 30 inches wide by 17 inches thick, broken into four pieces

to show the influence of forging, and the compactness and homogeneity of the metal from end to end. 4. A piece of *forged cast steel*, 17 inches wide by 9 inches thick, doubled up in the middle in a warm state under the hammer, without any indication of the slightest cracks. 5. A number of *cast-steel railway tires*, without a weld, as supplied to upwards of twenty railway companies. They are manufactured from oblong pieces, cut from ingots of steel, forged into shape. A hole is bored at each end; the two holes are united by a slot. The piece is then opened out into a ring by means of wedges. A locomotive driving-axle, with a pair of steel tires, was exhibited from the Great Eastern Railway, having run 66,180 miles without having been re-turned, the weight of the engine being 28 tons, and the driving load 10 tons. A pair of cast-steel engine-tires, 3 feet 6 inches in diameter, from the North London Railway, with $8\frac{1}{2}$ tons weight, had run 77,000 miles without re-turning. 6. Several *large and heavy cast-steel crank-shafts* were exhibited; for example, a heavy cast-steel forging for an intermediate paddle-shaft, forged under a 50-ton hammer, $15\frac{1}{2}$ tons weight, forged from an ingot weighing 25 tons. 7. A *cast-steel screw-propeller*, 9 feet in diameter. 8. A *cast-steel pump-rod*, 30 feet long, 5 inches diameter, for mines. Such rods are forged 60 feet in length. 9. *Cast-steel guns*, from $3\frac{1}{2}$ to 9 inches bore; outside and inside finished and polished. The largest weighed 18,000 lb., and was forged from an ingot of 50,000 lb.

M. Krupp is erecting large rolling-mills for making cast-steel plates and rails, with a steam-engine of 2,000-horse power. He hopes to roll plates sufficiently large to form locomotive boilers from a single sheet of metal, with a single row of rivets, with rolls of 15 feet in length; also armour-plates 1 foot thick. In 1851, he exhibited his maximum forging of only 4,500 lb. weight. In 1862, he exhibited ingots of ten times the weight, and finished articles of twenty times the greatest single weight supplied in 1851.

The Mersey Steel and Iron Company, Liverpool, exhibited a *large crank-shaft* and other forgings. The crank-shaft was rough from the hammer, and weighed from 24 to 25 tons; it was made to the order of Messrs. John Penn & Son, for a sister ship to the *Warrior*.

MM. Cail & Co., Paris, exhibited a number of forgings of wheels and other pieces—several of them somewhat complicated—well executed.

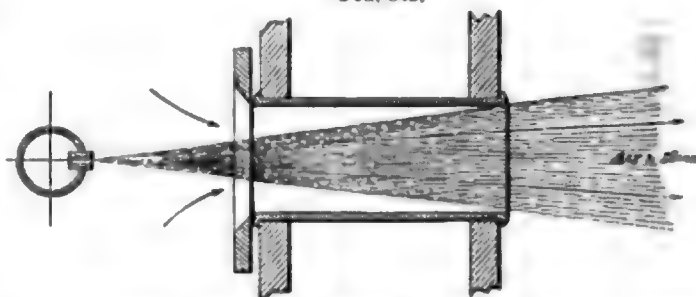
CHAPTER II.

FIREBARS AND SMOKE-CONSUMING APPARATUS.

Mr. D. K. Clark, London, exhibited his *smoke-consuming apparatus* at work upon the boilers

which supplied steam to the Western Annex. The supply of air for consuming the smoke is introduced at the front of the furnace, through the door, which is fitted with a flap-valve, hung from the upper edge to regulate the supply. The entering air impinges upon, and is deflected upwards by, a sloping baffle-plate fixed on the inside of the door, and strikes upon a horizontal plate fixed across the furnace just above and inside the doorway. Three small steam nozzles are here introduced, above this plate, and they meet with and absorb the current of air thrown upwards towards them, in virtue of their powerful suctional action. The mixed currents of steam and air are projected over the surface of the fuel, towards the bridge or throat of the furnace, and they thoroughly intermix the air with the smoke discharged from the fuel, and consume it on the spot; whilst the additional draught over the bridge, caused by the projected currents, in combination with the heat derived from the combustion of the smoke, increases the supply of steam, as compared with a non-consuming furnace. The original application of the suctional force of steam in jets for the purpose of consuming smoke, by the forcible induction of ordinary atmospheric air, was patented by Mr. Clark in 1857, as already described (see page 4, *ante*); and is illustrated by the annexed figure, which should have accompanied the former description (fig. 332). A jet of steam

FIG. 332.



SMOKE-CONSUMING APPARATUS, by Mr. D. K. Clark, London. (Section of an air-tube, and steam-pipe, with induction-jet of steam, applicable to the firebox of a locomotive engine.)

is directed into a tubular opening in free communication with the external air, through which a strong current of air is excited, in virtue, partly of the adhesion, and partly of the suctional action of the steam, and is delivered into the furnace.

The *feed-water heater* exhibited by Mr. Clark has also already been described (see page 10, *ante*).

Mr. J. L. Clark, London, exhibited *smoke consuming firebars*, of which the alternate bars are moved diagonally upwards and downwards, for the purpose of loosening clinkers, and dropping ashes, consuming smoke, and keeping up a clear fire.

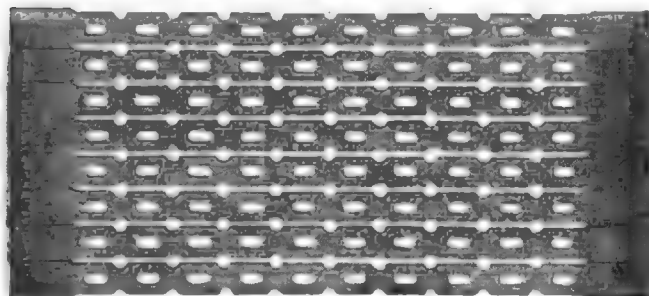
Messrs. Colquhoun & Thomson, London, exhibited *movable girder firebars*, of which every alternate bar is traversed back and forwards longitudinally.

Mr. R. Harlow, Stockport, exhibited a drawing of a *multitubular firebridge and heat-generator*.

Mr. W. A. Martin, London, exhibited *rocking firebars*. The bars are rocked by hand upon a central bearing, by which they are sustained, in two sets of alternate bars, so as to cross each other.

Messrs. E. Murray & Co., London, exhibited *moving argand firebars*, for supplying air by means of "air-conductors." The bars are 2 inches thick, with $\frac{1}{8}$ -inch interspaces, and air-slots down the sides and through the body of each bar. As the supply of air for the central slots is provided by clear openings made through the

FIG. 333.



MOVING ARGAND FIREBARS, by Messrs. E. Murray & Co., London.

sides of the bars, they are in this respect lighter and stronger than ordinary bars, and are more easily kept cool (fig. 333).

Mr. W. Stratford, London, exhibited an "air-diffused and smoke-consuming furnace," in which the bars are 2½ inches thick, with ½-inch interspaces, and formed with two rows of slot-holes for air through the body of the bar, with slots at the sides.

CHAPTER III.

TUBES, RODS, WIRE, ETC.

Messrs. Newton, Keats, & Co., Liverpool, exhibited—(1.) Articles of copper and brass—*plates, sheets, bolts, tubes, wires, &c.*, for engineers' and general uses. Of these, a few will be noticed:—

1. A rectangular *copper firebox-plate* for locomotives, 16 feet 6 inches long, by 4 feet 5 inches wide, and ½ inch thick, weighing 15 cwt. 0 qr. 21 lb. 2. A *very thin sheet of copper*, 15 feet long, and 4 feet 6 inches wide, weighing only 1¼ cwt., and being about $\frac{1}{30}$ inch in thickness. 3. *Copper bolts* were from $\frac{3}{4}$ to 1½ inch in diameter, and 21 feet long; they were partially rolled, and then finished by being drawn through steel dies upon a draw-bench, to render the metal dense, and to make the bolts more truly cylindrical than can be effected by rolling only. This is a point of some importance for screwed stay-bolts. 4. *Copper tubes*, made seamless or jointless, from 1½ to 5 inches diameter, for steam and other purposes—better than brazed tubes.

5. *Copper teach, or pan*, semispherical, 4 feet in diameter, with a flange 4½ inches wide, weighing 4 cwt. 1 qr. 7 lb. 6. Strings of *round and square copper wire*; the heaviest string was one of round wire, ½ inch in diameter, 77 lb. weight; the longest was one of No. 20 wire-gauge, 64½ lb. weight, upwards of 20,000 feet in length. One string of No. 19 wire-gauge weighed 72 lb. These are much heavier than copper wire usually made. 7. Of the brass goods, the heaviest piece was a *wrought-brass air-pump rod*, turned and polished, 6½ inches in diameter, 10 feet 7 inches long, 11 cwt. 2 qr. 4 lb. weight. Attached to it, a piece of the same metal, weighing 3 lb., was shown, drawn out into *fine wire*, No. 32 wire-gauge, two miles in length, to prove its tenacity and ductility. A rod of so large dimensions is rarely required for marine engines of the prevailing forms of construction. 8. The next article of importance was a *heavy rolled brass tube-plate*, for the surface condenser of a marine engine, 5 feet 9 inches, by 5 feet 2 inches, by $\frac{3}{4}$ inch thick, weighing 10 cwt. 1 qr. 7 lb. 9. *Seamless brass tubes*, from ½ to $\frac{3}{4}$ inch in diameter and 12 feet long, for the tubing of surface condensers. 10. *Seamless brass tubes*, manufactured on Keate's patent, 1½ to 5 inches diameter, for locomotive and marine boilers. 11. *Yellow metal bolts*, $\frac{3}{4}$ to 1½ inches diameter, and 21 feet long. 12. Strings of *brass wire*, from No. 5 to No. 22 wire-gauge, weighing from 29 lb. to 35½ lb.

(2.) The same exhibitors showed a selection of *rollers, cylinders, and bowls*, for working upon textile fabrics, which may here be noticed. In the manufacture of printing and embossing rollers, the great aim is to obtain a fine perfect surface to receive the engraving, for the smallest defect in the surface is printed as a blemish upon the cloth; and not only is the first surface required to be perfect, but the printer expects to be able to turn down the roller when the first engraving is done with, to provide a new surface for re-engraving, and to repeat the process so long as there is metal enough left to work with:—1. The largest roller exhibited was a *handkerchief roller*, 38 inches long, with a circumference of 47½ inches, and 14½ inches bore, weighing 282 lb. It presented a surface for engraving amounting to 12½ square feet, entirely free from blemish. 2. The *singeing-plates* were of copper, one of which was 7 feet 8 inches long, and weighed 426 lb. They are thick and narrow, and arched into a sort of bridge. When in use, they are heated red-hot, and the cotton cloth is passed rapidly over them, to singe off the nap before being printed upon. 3. Two *copper sizing cylinders*, and a *brass bowl* for calendering, were shown. These, as well as the printing rollers, are mounted upon iron centres or mandrils when in use.

The Broughton Copper Company, Manchester, exhibited a collection of *tubes*, brazed, seamless, moulded, spiral; and solid copper pipe.

FIG. 334.



TUBE MANUFACTORY AT KINGSTON METAL WORKS, BIRMINGHAM. MESSRS. ALLEN EVERITT & SONS.

Messrs. Eadie & Spencer, Glasgow, exhibited *wrought-iron tubes* up to 6 inches in diameter, $\frac{1}{8}$ inch thick, and 9 feet long, with a 5-inch branched pipe, &c.

Messrs. A. Everitt & Sons, Birmingham, exhibited *brass and copper tubes* for locomotives, coils, oval tubes; a coil of *copper wire* 2,000 yards long, 1 oz. in weight, &c. The accompanying figure of the interior of the tube manufactory of the exhibitor illustrates the process of manufacture (fig. 334.)

The Imperial Iron Tube Company, Birmingham, exhibited *iron, brass, and copper tubes*. The iron tubes are lap-welded.

1. An 8-inch wrought-iron pipe, $\frac{1}{8}$ inch thick; 6½-inch T-pipes; and 3½-inch cross-pipes.
2. A 1-inch iron pipe, turned into a coil 4½ inches in diameter, 2½ inches pitch.
3. A taper pipe, in seventeen coils, from 1½ to 2½ inch outside diameter.
4. Glass enamelled wrought-iron tubes and fittings.
5. Copper tubes, scarfed and brazed, 4½ inches diameter, $\frac{1}{8}$ inch thick.
6. 3½-inch brass tubes, $\frac{1}{8}$ inch thick, &c.
7. Hughes's taps, in which the plugs are made hollow, and form a portion of the thoroughfare; thus the pressure of the steam or water, flowing through the tap, is balanced, and the plug is free from liability to be tightened or loosened by pressure, or by unequal expansion.

Messrs. Lloyd and Lloyd, Birmingham, exhibited *wrought-iron tubes and fittings*, comprising a 6-inch tube. A piece of 2-inch *homogeneous metal tube* for boilers had been flattened and doubled up without any fracture, showing the toughness of the metal. Well-made pipes with six and eight branches were shown.

Messrs. J. Louch & Co., London, exhibited *union joints and pipe fittings*. Lead-pipe joints are made by flanging the ends of the pipes, and screwing them up with right-and-left-hand unions. 2. *Heap's pipe-cutter*, worked by a double hand-lever: the cutter is set by a screw on the handle.

Messrs. James Russell & Sons, Wednesbury, exhibited *iron*

tubes and fittings, showing 12-inch iron tubes $\frac{3}{8}$ inch thick, 12 feet long, for boilers; 12-inch steam tubes $\frac{1}{4}$ inch thick; hydraulic tubes, $\frac{3}{4}$ inch diameter outside; wrought-iron tubes with cast-iron head, a part of York and Benson's steam-boiler; a coil of $\frac{1}{2}$ -inch tube from 70 to 80 feet long; glass-enamelled tube. According to experimental tests conducted by the exhibitors, tubes of homogeneous metal, 3 inches external diameter, and No. 13 wire-gauge in thickness, were burst by a pressure of 3,600 lb. per square inch; and collapsed by a pressure of 1,400 lb. per square inch. Iron tubes of the same external diameter, and No. 11 wire-gauge in thickness, were burst by a pressure of 2,700 lb. per inch, and collapsed by a pressure of 1,200 lb. per inch. The tubes tested were from 3 to 4 feet in length.

Messrs. John Russell & Co., London and Manchester, exhibited *wrought-iron tubes* for boilers, &c., showing, besides large lap-welded tubes, a tube $\frac{3}{8}$ inch outside, formed into a coil $3\frac{1}{2}$ inches in diameter; a tube $\frac{5}{8}$ inch outside, coiled to $4\frac{1}{2}$ inches diameter; and a tube 1 inch outside, coiled to 8 inches diameter.

The Stephenson Tube Company, Birmingham, exhibited *seamless brass and copper tubes*, showing a solid-drawn copper pipe, $16\frac{1}{2}$ inches in diameter; an oval-drawn copper pipe, 3 inches by $\frac{3}{4}$ inch; an octagonal solid-drawn copper tube, 6 inches diameter, and 11 feet 3 inches long; the same in brass, $5\frac{1}{2}$ inches in diameter; a coil, 3 inches in diameter, of tube $\frac{1}{4}$ inch outside, and fully $\frac{1}{8}$ -inch bore.

CHAPTER IV.

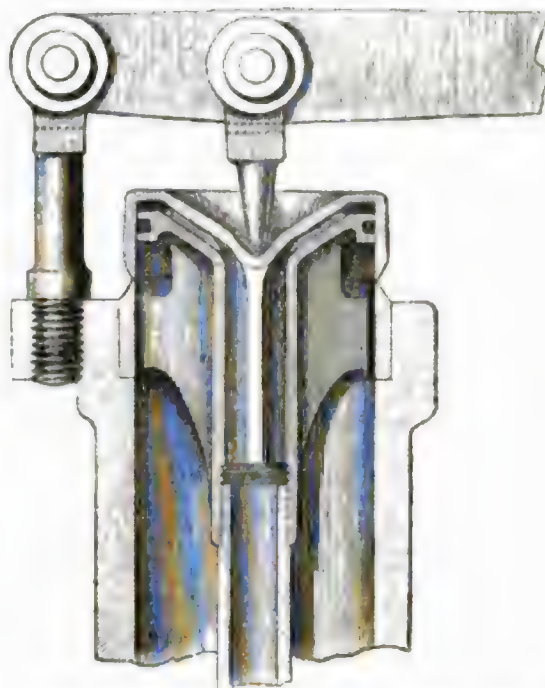
SAFETY-VALVES, WATER-GAUGES, WATER-FEEDERS, &c.

Messrs. Allen, Harrison, & Co., Manchester, exhibited, besides a collection of brass mounting, a *fusible-alloy safety-valve*, to give way when the water in the boiler falls too low. Plugs of fusible-alloy are let into the valve, which is fixed upon the boiler-flue over the fireplace. When uncovered by water, the plugs are melted out by the heat of the furnace, and the steam escapes into the fireplace.

Messrs. R. & L. R. Bodmer, London, exhibited *Mr. R. Bodmer's safety-valve*, designed to obviate the defects of safety-valves of the ordinary construction. With these the steam, when about to blow off, must, for this purpose, raise the valve from its seat; but the valve rarely rises more than $\frac{1}{16}$ inch from the seat, and the opening for escape is of course restricted to the same measure. The restriction of the opening to so small a quantity is owing probably to the instantaneous reduction of steam-pressure under the valve, so soon as a current outwards is established, when motion takes the place of

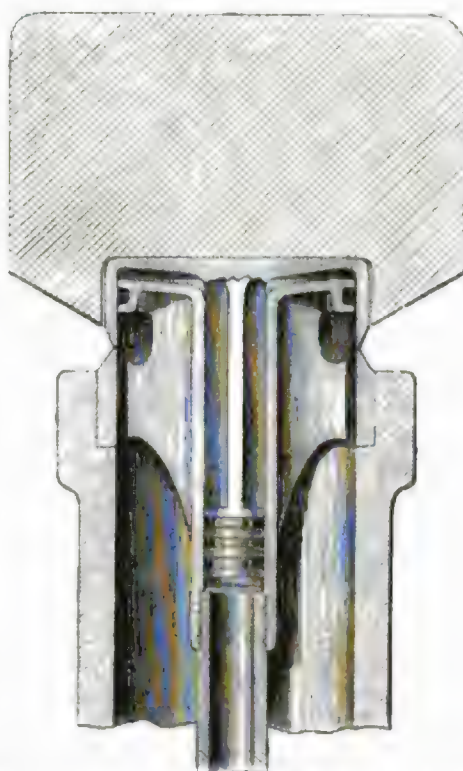
dead pressure. But the result is that the steam cannot in all cases escape so fast as it is generated, and the pressure consequently rises in the boiler considerably, and sometimes dangerously, above that to which the safety-valve is loaded. Mr. Bodmer's valve is so constructed that it

FIG. 335.



EQUILIBRIUM SAFETY-VALVE, with Weighted Lever, by Mr. L. R. Bodmer, London.

FIG. 336.



EQUILIBRIUM SAFETY-VALVE, with Direct Load, by Mr. L. R. Bodmer.

rises with a slight excess of pressure, and makes an aperture sufficiently large to allow all the surplus steam to escape, or at least as much as can pass through the opening from the boiler;

and this is effected by means of applying independently and maintaining the full boiler-pressure undiminished upon the under side of the valve, entirely separated from the current of steam blowing off. For this purpose the valve-cap is turned out on the under side, so as to form a cylindrical recess, to receive a steam-tight disc projected from the valve-seating—the valve-seat, or opening for the escaping steam, being below the level of the disc. Steam or water from the boiler is admitted, under pressure, through a central tube to the space between the disc and the top of the valve, and is thus totally isolated by the disc from the escaping current of steam below. This is an ingenious and no doubt effective safety-valve. Mr. Bodmer considers that a 4-inch valve on his principle is equal in efficiency to a common valve of 64 inches diameter (figs. 335, 336, page 363).

With a slight modification, valves on this principle may be constructed with a lifting area of exactly one square inch, less or more, whilst the valve may be 3, 4, or more inches in diameter.

Messrs. E. T. Bellhouse & Co., Manchester, exhibited, besides a horizontal engine, and a model of their twin steam-boiler, *Cowburn's oscillating direct-weighted safety-valve*. It is direct acting, without a lever, is freely suspended, so preventing adhesion or sticking to its seat, on which it rests with a spherical bearing, and is free to adjust itself to the vertical position (fig. 337).



FIG. 337.
COWBURN'S SAFETY-VALVE, by
Messrs. E. T. Bellhouse & Co.,
Manchester.

Messrs. T. Walker & Son, Birmingham, exhibited their *quadrant alarm water-gauge*, the object of which is to indicate, by a radial pointer, actuated by a steam-float, the level of



FIG. 338.
QUADRANT ALARM WATER-GAUGE,
by Messrs. T. Walker & Son,
Birmingham.

the water in the boiler, and to sound an alarm by means of a steam-whistle when the water-level gets too low. The float is suspended from the end of a lever working within a steam-tight cast-iron box, fixed upon and in free communication with the boiler. The axle of the lever is carried through a stuffing-box in the side of the box, and carries the pointer on its outer end, with a counterweight to balance the float. This apparatus is better than the common stone float with a rod passing directly through the stuffing-box in the top of the boiler, as the resistance from friction and the liability to stick in the stuffing-box is very much diminished by the introduction of the lever (fig. 338).

Mr. Francis Wise, London, exhibited *Featherstonhaugh & Wise's "boiler guardian,"* being a feed-water regulator, indicator, and alarm. By a motion from a copper float attached to the end of a lever within the boiler, a slide-valve is moved upon a three-ported vertical face within a steam-tight cast-iron box on the top of the boiler. When the water-level is too high, air or steam is admitted into the force-pump, and suspends the supply of water; but should that

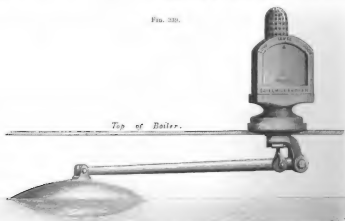
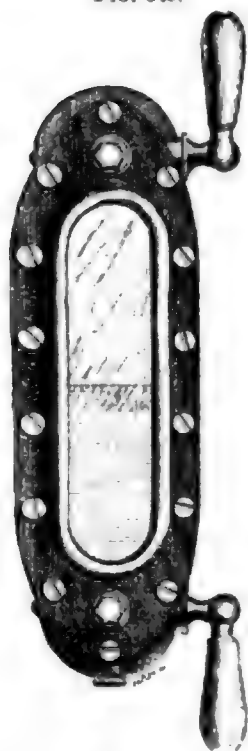


FIG. 339.
BOILER GUARDIAN (Featherstonhaugh & Wise's Patent), by Mr. F. Wise, London.

fail, the third port is uncovered, and conducts a current of steam to sound an alarm whistle (fig. 339).

Mr. J. Chandler, London, exhibited *flat-glass water-gauges*, which consist of metallic cases with glass fronts. They are neat and substantial, and afford a clear and satisfactory view of the water-level in the boiler. They are fitted either singly or, for still greater security, in pairs (fig. 340).

FIG. 340.



FLAT-GLASS WATER-GAUGE, by Mr. J. Chandler, London.

M. Lethuillier - Pinel, Rouen, exhibited *magnetic water-gauges*, in which a magnet, moved by a float inside the boiler, causes a small steel roller to rise and fall outside a face-plate on the top of the boiler, and indicate the variation of the level of the water.

Messrs. Routledge & Ommanney, Manchester, exhibited a *self-acting boiler-feeder*. A close chamber is filled with steam from the boiler; the steam is then shut off, and feed-water from a higher level is admitted into the chamber, condensing the steam, and forming

a vacuum. The chamber being, therefore, filled with feed-water, by atmospheric pressure, a

double communication is opened with the boiler—above with the steam, and below with the water in the boiler.

The water then gravitates from the condensing chamber into the boiler, and its place is again occupied by steam, to be again condensed, and the chamber re-filled. A vacuum of 12 lb. per inch is formed in this apparatus, and about a fourth of the whole quantity of water delivered at one charge

is fetched by means of the vacuum from the hot well of the engine or from any other source. The exhibitors state that this apparatus will feed with water at 212° Fahrenheit, though it does not appear how a vacuum can be maintained at 212°; also, that it will fetch cold water from a depth of 20 feet below the feeder, and warm water, at 90°, from a depth of 15 feet (fig. 341).

Messrs. Sharp, Stewart, & Co., Manchester, —also M. Flaud, Paris,—exhibited *Giffard's water-injector*, which has already been noticed (see pages 26 and 144).

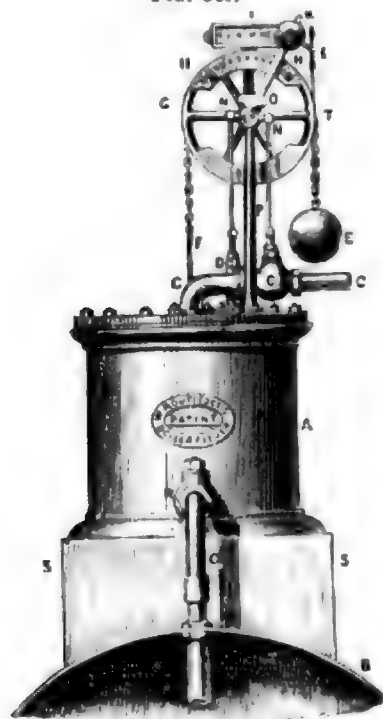
M.M. Gargan & Co., Paris, exhibited a *self-feeding apparatus for boilers*, on the principle of that of Messrs. Routledge & Ommanney, by the alternate condensation of steam and the formation of a vacuum, and the filling of the vacuum from the supply of water. A cylindrical slide is moved up and down, in which a central chamber having three ports communicates alternately with the steam and the water of the boiler, through two of the ports, and with the water supply through the third port.

M. Achard, Paris, exhibited an *electro-magnetic feed-water regulator*, which combines the functions of regulating by self-action the supply of feed-water to the boiler, and of giving notice by ringing a bell when the water is too low or too high, when the pressure of steam is too high, when the feed-pump is out of order, and when the apparatus itself is out of order. By means of a current of electricity, the action of the feed-pump is suspended or restored, whilst the pump continues uninterruptedly in motion. The agency of the electric current is employed only to connect or disconnect certain organs, not to provide mechanical action, the connection being made or unmade by means of a float on the water. Many of this apparatus are at work in France, where they are said to give satisfaction; but the apparatus does not operate when the engine is at rest.

Messrs. Wm. Oxley & Co., Manchester, exhibited a *steam-trap*, for draining off water from steam-pipes. A round float of tinned copper is fixed on the stem of a small brass valve within a chamber, into which the steam and water are delivered. The flotation of the float in water exceeds the pressure on the valve, and therefore it opens the valve, and permits the water to escape. The float descends as the water escapes, and again closes the valve until the water again accumulates. The exhibitors showed also an *oil-can*, fitted with a valve inside, which, by the action of a spring, closes the orifice of the spout and prevents waste. When the oil is to be delivered the valve is opened by pressing with the thumb upon a stud.

M. A. Pougault, Decize, Nièvre, exhibited a "*drain apparatus*," for trapping water from steam-pipes, which acts on the principle of Messrs. Oxley & Co.'s, above described.

FIG. 341.



SELF-ACTING BOILER-FEEDER, by Messrs. Routledge & Ommanney, Manchester.

form the vacuum under a head pressure; the remainder of the charge—three-fourths—can be

CHAPTER V.

PRESSURE-GAUGES, ETC.

The original pressure-gauge consisted of a column of mercury in an upright glass tube, open at the foot, standing in a cup of mercury and closed at the top, containing a quantity of air. Amongst other objections was the difficulty of correctly reading off the pressure from the scale in the upper ranges, owing partly to the minuteness of the subdivisions, and partly to the distortion of the scale by the refraction of light through the glass. In the pressure-gauges exhibited, the use of the vertical column, except in Mr. Allan's gauge, was abandoned for metallic springs in various forms, the most common of which consisted of thin flexible discs secured at the circumference, and exposed to the pressure on one of their surfaces—the resulting deflection of the plate being transmitted through a rack and pinion to a pointer on the axis of the pinion, by means of which the motion is magnified and the pressure indicated upon the dial.

Messrs. Smith Brothers & Co., Nottingham, exhibited *pressure and vacuum gauges*, in which a volute spring receives the pressure through an india-rubber disc stretched across the aperture of the pressure-tube, to transmit the pressure whilst preventing the passage of steam or water into the instrument.

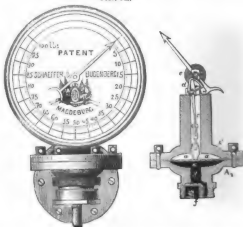
Messrs. G. Salter & Co., West Bromwich, exhibited, besides the well-known spring-balances for which they are celebrated, a selection of *pressure-gauges*, in which, as in Messrs. Smith's gauges, the pressure acts through a tight india-rubber disc, on which a metallic plate is placed, with a rod in connection with the mechanism, to receive the resistance from a helical spring.

Messrs. B. A. Grantoff & Co., London, exhibited *steam and vacuum gauges*, in which two hollowed steel discs are applied, and jointed together at the circumference, leaving a hollow space between them. The pressure collapses the chamber, and thus gives the required action, which is the combined deflection of two discs.

M. E. Bourdon, Paris, exhibited the *pressure-gauge* well known by his name, in which a coil having the section of a flattened tube is employed to receive and indicate the pressure. When steam, or water under pressure, is admitted into the coil, the pressure tends to uncoil or straighten the tube, in proportion to its intensity; and when the pressure is relaxed or withdrawn, the tube returns towards its original form. The motion of the extremities of the tube is in proportion

to the pressure applied, so that the indications are equal for equal increments of pressure. In the steam-pressure gauge of the simplest form, a coil of a little more than one convolution is employed, one end being attached to a stopcock in connection with the boiler, and the other end carrying an index-pointer traversing a graduated scale. For a greater range of motion the end of

FIG. 342.



STEAM-GAUGE, by Messrs. Schiffer & Bodenberg, Magdeburg. *a*, corrugated steel plate to receive the pressure. The action is transmitted by the parts *b*, *c*, *d*, regulated by the spiral spring *e*.

the tube is linked to a toothed sector, which turns a pinion on the spindle of the pointer. In

FIG. 343.



MARINE GAUGE, by Messrs. Schiffer & Bodenberg.

another form a twisted tube like a quick-threaded screw is employed; steam being admitted par-

tially untwists the tube, and thus gives motion to the index-pointer. A gauge for very high pressures is made by connecting two curved tubes, which are filled with water in free communication, one of which is exposed to pressure externally, and transmits it to the other by internal hydrostatic action. The action is communicated from the second tube to a pointer in the usual way.

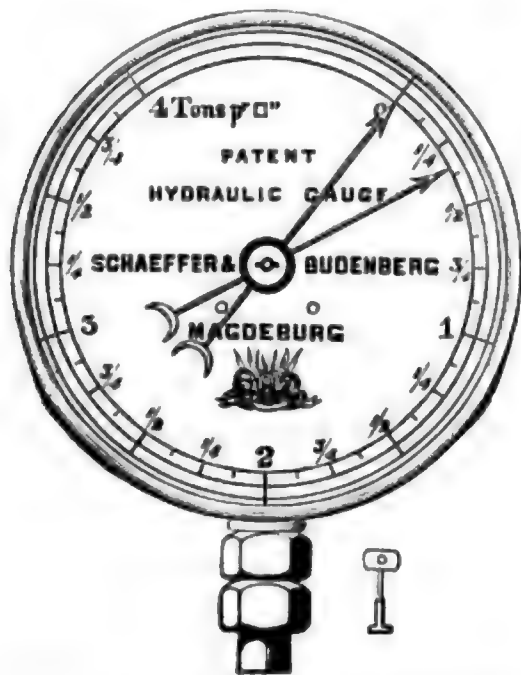
M. Bourdon also exhibited a mode of raising water by jets of steam, in principle like Giffard's injector; it was invented before this apparatus.

MM. Schaffer & Budenberg, Magdeburg, exhibited *gauges and other steam-engine fittings*.

1. *Steam-gauges*, in which the pressure is received upon a corrugated circular steel-plate, which is coated with silver on the steam side, to prevent corrosive action. A spiral spring is introduced at the back of the pointer, to take up any looseness of the working parts (figs. 342 and 343).

2. *Hydraulic gauge*, for presses and pipes, fitted with a "maximum pointer,"—that is, a loose pointer, to show the highest or lowest pressure applied. The dial is graduated into pounds or tons, up to 10 tons per square inch (fig. 344).

FIG. 344.

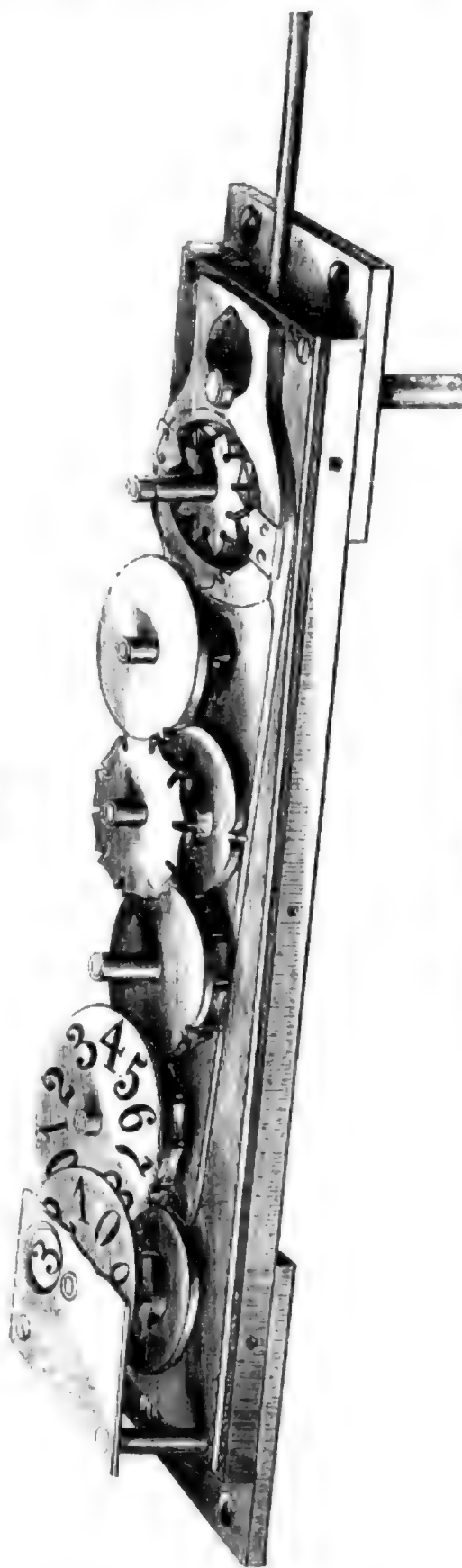


HYDRAULIC GAUGE, by Messrs. Schaffer & Budenberg.

3. *Engine-counter*, made without springs. The lever for taking the oscillating motion or reciprocating strokes of a steam-engine works an excentric, which moves a long lever laid along the bed of the counter, and pivoted at the other end. The lever is fitted with two hardened steel teeth, which, alternately striking into a wheel with ten teeth, analogously to a clock escapement, advance it by one tooth, or one-tenth of a revolution for each vibration, causing it to make one turn for ten strokes. By appropriate gearing the successive wheels and dials make one turn for ten of the wheel preceding, and thus with six dials the instrument counts up to

1,000,000 (fig. 345). 4. *Syphon-box or steam-trap*, to remove the water by condensation of steam or otherwise from steam-pipes, without any loss of steam. It is placed sufficiently low to allow the water to flow into it. The water

FIG. 345.

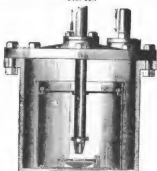


ENGINE COUNTER, by Messrs. Schaffer & Budenberg.

raises the float inside, which is open at the top, until it is arrested by the central escape-tube; the water, by continued influx, overflows into the float, sinks it, and opens a valve at the

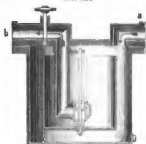
bottom of the float, when the water is finally forced up the tube by the steam-pressure and carried away. The valve closes again before steam can escape, and the self-acting process is repeated. A check-valve in the escape-tube prevents the return of the water that has been expelled (figs. 346 and 347). 5. *Double relief.*

FIG. 346.



STEAM-TRAIT, by Messrs. Schäffer & Budenberg.

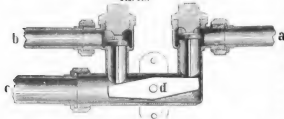
FIG. 347.



STEAM-TRAIT (new design), by Messrs. Schäffer & Budenberg.

valve, for removing water from steam-cylinders. A tube from each end of the cylinder is

FIG. 348.

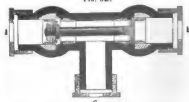


DOUBLE RELIEF-VALVE, by Messrs. Schäffer & Budenberg. a, b, tubes from the two ends of the cylinder; c, escape-pipe; d, reciprocating lever between the valves.

connected to one of a pair of valves which alternately are subjected to the pressure of the

steam in the cylinder, and closed. Whilst one valve is closed, the other valve is at the same time opened by means of a lever, acted upon by the closed valve, and the water flows off through an escape-pipe (fig. 348). In another and simpler plan, the valves are placed horizontally and are directly connected to each other, dispensing with the lever, and by the same action are opened and closed alternately (fig. 349). These valves are available also for relieving back-pressure in the cylinder. 6. *Dyna-*

FIG. 349.



DOUBLE RELIEF-VALVE (simplified design), by Messrs. Schäffer & Budenberg.

FIG. 350.

moneter, in which a pair of solid steel bars, slightly curved, are framed together face to face, with a hook at each end to make connections. The strain tends to straighten the springs, and the action is communicated by the usual means to a pointer on a dial fixed in the apparatus, to indicate the load or strain. The springs are guarded by a pair of rods moving loosely in their bearings, which take the strain in case the springs fail (fig. 350). 7. *Winding-indicator*, for coal-mines, to indicate by two pointers the position or the height of the cages in a pit. The motion of the apparatus is derived from the winding-engine, and is imparted to a screw which revolves in unison with it. A slide connected to an endless band passing over two pulleys, as in a band-saw, is traversed to and fro by the screw, and causes the wheels, which carry pointers with them, to turn on their axles, and indicate the progress of the

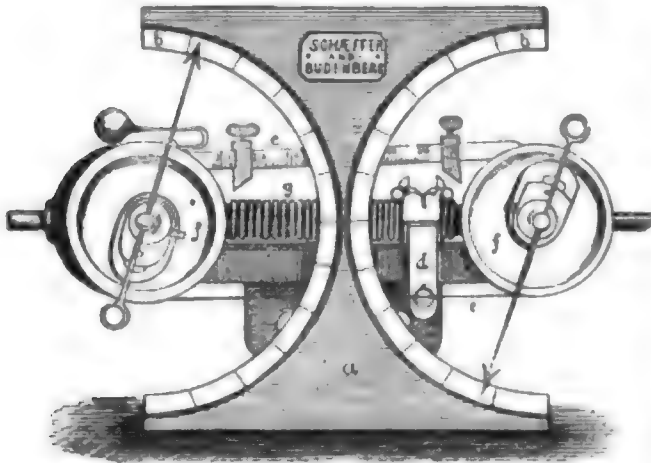


DYNAMOMETER, by Messrs. Schäffer & Budenberg.

cages respectively on two semicircular scales. A bell is struck at the instant that the cages

are at their destination by means of a couple of triggers carried by the slide, which lift alternately a couple of studs fixed at each end of a graduated lever, and give the fall for striking the bell (fig. 351). 8. *Low-water indicator and*

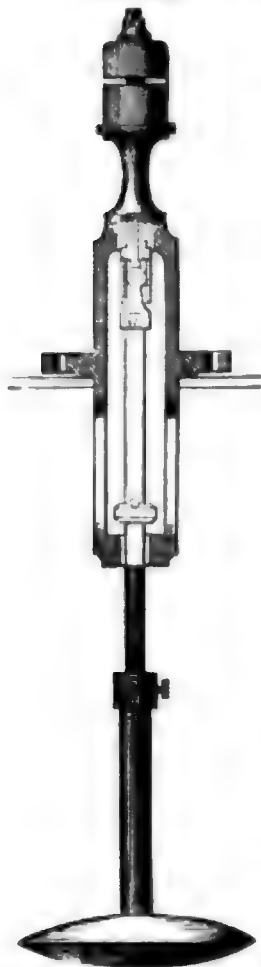
FIG. 351.



WINDING INDICATOR for Coal Mines, by Messrs. Schaeffer & Budenberg. *d*, the slide; *e*, the endless band over the wheels *f, f*; *g*, the traversing screw; *c*, the lever for striking the bell.

whistle, for a boiler, acts by means of a float connected to a stem within a steam-tight case. The stem is surmounted by a small globe, which fits and slides easily in a socket at the base

FIG. 352.



LOW-WATER INDICATOR and WHISTLE, by Messrs. Schaeffer & Budenberg.

the variations of pressure in the cylinder, the

figures described by either M'Naught's or Gooch's indicator are nevertheless susceptible of being reduced to the normal form, the disturbances being eliminated from them.* In Richards's indicator the weight of the moving parts is reduced as much as possible; a short spring is used, and the range is multiplied by a lever formed with another lever into a parallel motion, to carry the pencil in a straight line. The pencil is, in fact, a pointed brass wire, which marks on prepared metallic paper, and is lighter, stronger, and more durable than black-lead pencils. A common pin with a blunt point makes a good line. The indicator-diagrams taken by this indicator from locomotive engines at high speeds, are very steady, and apparently very accurate (fig. 353, page 370).

CHAPTER VI.

SALINOMETERS.

Sea-water in the ocean contains a certain quantity of salt, in the proportion of 1 lb. of salt to 32 lb. or 33 lb. of water; and as all the water evaporated is fresh, all the salt is left in the boiler, which would cause its destruction if not removed. This is done by blowing out, at intervals, a portion of the partly saturated water from the boiler. Scale is not formed in a boiler until the water has reached a certain degree of saltiness, and if it is kept below that point the boiler will be kept clean, but if allowed to get above, incrustation takes place and continues as long as it is above. Hence the necessity of keeping the water in the boiler at a proper and uniform degree of saltiness, resulting in a saving of fuel, as well as a saving of the boiler.

In most steamers a much greater quantity of hot water is blown off than is necessary, and even then the boilers are not kept clean, because it is not always blown at the proper time. Large quantities of hot water are often blown off when not necessary, and at other times when water ought to be blown off it is not done, except there be means for ascertaining when it is necessary, or how much is required to be blown off. The salinometer is simple in its construction, and certain in its action; and indicates at all times the exact degree of saltiness of the water in the boiler. Thus, the quantity of water necessary to be blown off can be regulated with certainty, and reduced to the smallest amount for the safety of the boiler and for economy of fuel.

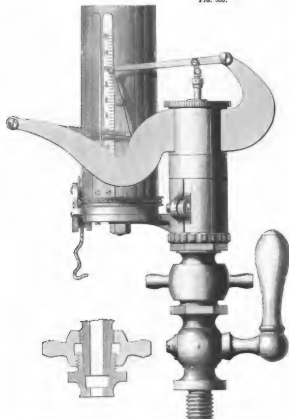
Mr. M. A. Soul exhibited *Long's salinometer*. The ordinary salinometer-case consists simply of a tube communicating with the boiler, and

* For an account of these indicators and their performances, with locomotive engines, see "Railway Machinery," page 63.

containing the hydrometer, the communication with the boiler being made by means of a pipe which passes from the bottom of the case to

is connected with the boiler by means of a pipe, which passes from below the water-line of the boiler, through the bottom, and along the axis of the supply-tube to a point near its top, where it opens into the supply-tube by means of a number of vertical slits. The main tube in which the hydrometer floats is not connected with the boiler, but

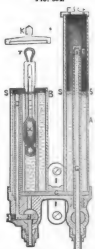
FIG. 353.



RICHARD'S INDICATOR, by Mr. C. T. Porter, New York (now of Manchester).

below the lowest water-level of the boiler, and provided with a stopcock, which, when turned, permits the pressure of steam in the boiler to force the water up in the case, and float the hydrometer. But the ebullition in the case, produced by the escape of steam under a reduced pressure, throws a great deal of hot water out of the instrument, and subjects the observer to the danger of being scalded, and at the same time causes such violent oscillations as to risk the safety of the hydrometer, and prevent its being read until the stopcock is closed, when very frequently there will not be found enough water in the instrument to float the hydrometer. The improvement of Mr. Long consists in adding to the ordinary salinometer-case another tube connected with it at the bottom. This supply-tube

FIG. 354.



LONG'S MARINE SALINOMETER, by Mr. M. A. Soul, London.

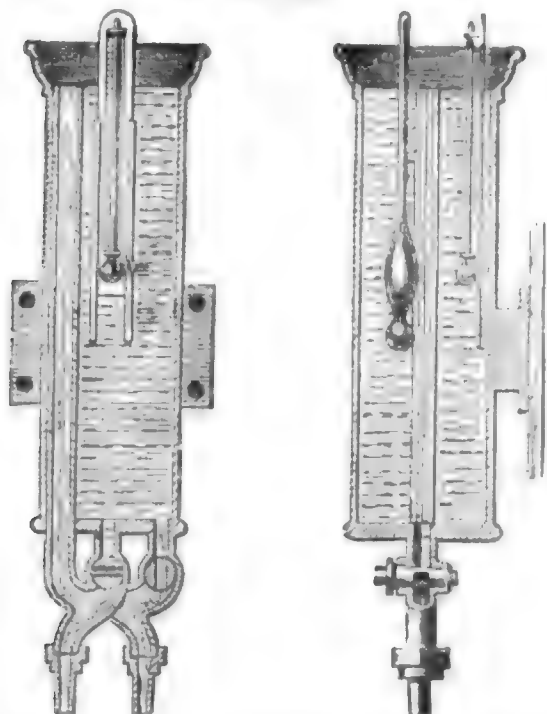
has a waste-pipe, by which any escape of water may be carried off, and proper supports for a thermometer. When by turning the stop-cock the water is forced from the boiler into the supply-tube, it is thrown, not upwards, but against the side of the tube, owing to the mode

of its escape. The steam which accompanies it is separated, and escapes through openings in the cover, and the water falling to the bottom passes through the tube of communication, and rises to the same level in the salinometer-tube, in which the hydrometer floats tranquilly, and may, therefore, be read speedily and accurately. By means of the waste-pipe, a current may be kept passing through the instrument, which is thus always in action, and may be read by the engineer at a glance as he passes it in the performance of his other duties (fig. 354).

Messrs. Fricake & Gathercole, London, exhibited *How's salinometer* — a simplification of Long's apparatus, — consisting of a single cylinder into which the water is admitted from below, regulated by a cock. By an overflow-pipe

the surplus water is carried off. Inside is placed a thermometer to show the temperature of the water there; also, a hydrometer floating in the water, at a height corresponding to its density or saltness (figs. 355).

FIGS. 355.



How's SALINOMETERS, by Messrs. Frieake & Gathercole, London.

CHAPTER VII.

STEAM-ENGINE GOVERNORS.

The first governor for regulating the speed of steam-engines was invented by James Watt, who patented it in 1784. It was the two-ball governor, still employed for the purpose in land engines, notwithstanding many attempts to supersede it. For practical purposes, the ball governor, rightly adapted, is generally sufficient, and hence its universal application to stationary engines.

In the application of governors to marine engines, two-ball governors, variously arranged with horizontal spindles, were tried, in which the action of a spiral spring was substituted for the force of gravity; but they were found defective, as the pendulous motion of the balls, with the movements of the vessel, deranged their functions and destroyed their action. This defect arose from the want of balance in the governor itself, to preserve it unaffected by the motion of the ship. The first balanced governor was invented by Mr. Silver, of New York. It had a single straight arm with a ball at each end, and connected to the spindle by the centre of its length. When at rest, the spring lays the arm alongside the spindle; when in motion, the centrifugal force drives out the balls in counter-action to the spring, and action follows upon

the throttle-valve. But, inasmuch as the rolling or pitching of the vessel alters the position of the spindle with respect to the balls which tend to revolve in the same plane, and thus, by an inverse action, to affect the throttle-valve, without any relation to the speed of the engine, this defect was remedied by the addition of another arm and pair of balls to cross the first one, constituting a four-ball governor. But another difficulty was experienced: when the racing of the engines commenced abruptly, the balls, resisting the sudden start, broke the gearing or slipped the belt, in either case failing to act with the necessary promptitude. In a more recent instrument—the fly-wheel governor—this difficulty also has been overcome by Mr. Silver. The balls are replaced by a fly-wheel turning loosely on the spindle within limits, the inertia of which resists sudden changes of speed, and allows the spindle to turn in advance of the main or heavy portion of the instrument; by the connection of the fly-wheel with the throttle-valve, it closes the valve. The inertia of the fly-wheel, opposing resistance to the sudden start of the engine, is the direct cause of action. Motion is given to the fly-wheel by means of a spring connected to two toothed quadrants hung on pivots fixed to the spindle, and gearing with a small bevel-wheel fixed on the nave of the fly-wheel. Thus, any sudden start of the engine acts instantaneously on the valve, and shuts it, at the same time that all the force of the sudden jerk is taken up by the spring, and thus the breaking of gearing and slipping of the belt is entirely obviated in this instrument. The spring, being thus loaded, discharges its tension, communicated partly to the fly-wheel, by endeavouring to increase its velocity, and partly in reopening the valve. To limit the speed of the fly-wheel, as it would otherwise run anyhow, and lose its power as a regulator, four fan-blades are attached to the arms of the wheel, which, increasing in their resistance to the air, in the ratio of the square of the velocity, put the spring in tension, when the fly-wheel attempts to exceed its normal speed, and close the valve.

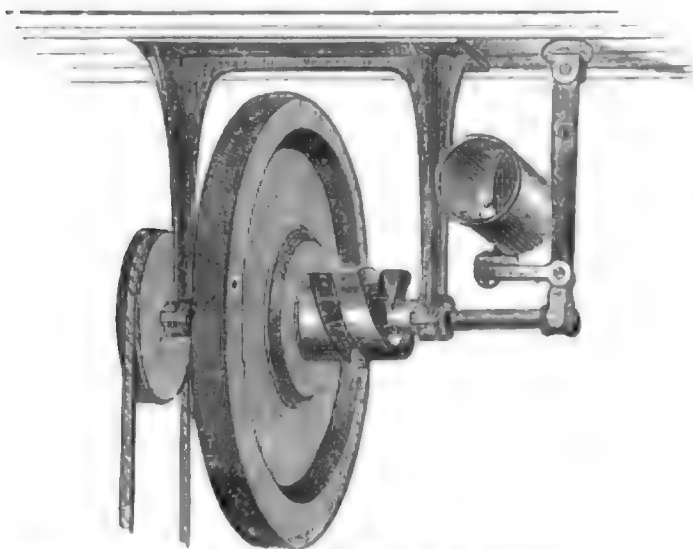
The difference between the action of the fly-wheel governor and that of the four-ball governor is, that the latter regulates the throttle-valve directly, according to the centrifugal force; whereas the former does it indirectly, but nevertheless more promptly, by limiting the speed of the fly-wheel by means of the fans.

Mr. J. Basire, London, exhibited a model of *Miller's marine governor*. It consists of a fly-wheel, to which is attached one-half of a cylindrical boss: the other half of this boss, which also forms the sliding-sleeve, is allowed to move longitudinally on the spindle, but follows its rotating motion; whereas the fly-wheel, with the first half of the boss, is loose on the spindle. The boss is cut in two halves, at an angle of about 60 degrees to the direction of the spindle. The fork-lever, which is worked by the sliding-sleeve, for the purpose of opening and shutting

the throttle-valve, is provided with a weight or spring, intended to force the one half of the boss up against the other half attached to the fly-wheel, so as to replace it in its first position, when pushed back by the action of the governor. As the fly-wheel resists by its inertia any sudden change of motion, the one half of the boss will be forced back by the other half attached to the fly-wheel, and thereby cause the valve to be shut; it is afterwards opened again by the weight or spring. This is the case when any sudden starts occur; but when the increase of speed is gradual, the weight or spring on the fork-lever will press those two slanting surfaces of the boss together, in frictional contact, and thus may fail to shut the valve. Moreover, the pitching of a ship will often interfere with the force of gravity of the weight, and thus open the valve when it ought to be shut, and *vice versa*. In this governor there is not any counterbalance to the momentum of the fly-wheel, and the regulating power of the instrument is greatly impaired by being at times allowed to run away.

Mr. M. A. Soul, London, exhibited a model

FIG. 356.



MERITON'S MARINE GOVERNOR, by Mr. M. A. Soul, London.

of *Meriton's marine governor*. It consists of a fly-wheel, to which is attached a small cylindrical boss, with two spiral grooves cut one in each side; and in these grooves work two studs fixed on one end of the sliding-sleeve, which follows the movement of the spindle, driven, as usually, by a band from the screw-shaft. As the fly-wheel is allowed to turn loose on the spindle, so as to act by its inertia, any sudden start of the engine will immediately shut the valve, and thereby carry the studs to the farthest end of the groove. When once arrived there, some contrivance is required to replace them in their first position, and thereby open the valve again. In this governor the valves must be reopened by hand (fig. 356).

M. Taurines, Paris, exhibited a drawing of a *dynamometer*, for which he claims also the

property of acting as an instantaneous regulator for all kinds of engines—land, screw, and paddle. A fly-wheel with a double rim—an outer and an inner—is placed loosely upon a spindle in connection with the engine, being to a certain extent free to rotate. The inner rim is connected by means of segmental springs and rods to a disc attached to a carriage connected to the lever of the throttle-valve. When the speed of the spindle is increased, the fly-wheel, resisting the change of speed, extends the springs, which move the carriage so as to close the valve; whereupon the speed of the engine falls, the springs revert to their first position, and the valve is reopened. This governor is bulky, and it would be very difficult in most marine-engine rooms to find space for it.

MM. Albaret & Co., Liancourt (Oise), exhibited a *governor*, having a fly-wheel with a heavy iron ring, swivelled by its centre upon an upright spindle. At the regular speed, the ring is retained in an oblique position; when the speed rises, the ring leaves its oblique position, and approaches a horizontal position at right angles to the spindle, and by suitable connections closes the valve.

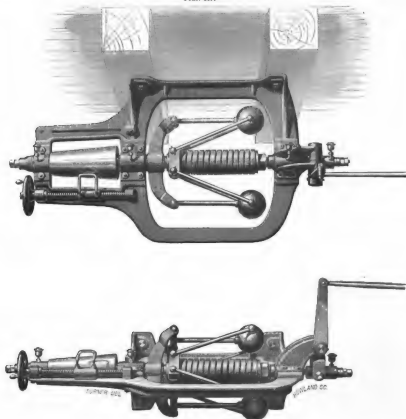
MM. Farcot & Sons, Paris, exhibited a *two-ball governor, with crossed arms*, upon their steam-engine. The arms, crossing each other through the spindle, below the points of suspension, are hung from the opposite sides of the spindle; and the vertical height of the conical pendulum remains nearly constant for different speeds of the balls, inasmuch as the point of intersection of the crossed arms, being the apex of the cone of revolution, ascends at the same rate as the plane of revolution of the balls when the speed is increased. Thus the governor-balls will remain nearly in equilibrium, in every angular position, at the speed for which the apparatus is adjusted. The height of the pendulum being, however, a little shorter when the balls are in their extreme positions than when in their midway positions, a dead weight or counterpoise is added, acting with a variable leverage, of which the angle varies as the squares of the velocities due to the heights of the pendulum, compared with the square of the given velocity of the pendulum—the centrifugal force increasing also as the square of the velocity. The speed of the regulator is variously adjusted, as required, by an adjustment of the counterpoise on the lever. This is a facility peculiar to the crossed governor. As the arms are crossed, they revolve on both sides of the axis of rotation, or centre line of the spindle, though of course greatly preponderating on the side of the ball on each arm; still the opposed sections of each arm vary a little with the spread of the arms, as the greater the spread the greater also is the portion of the arm that revolves on the side of the ball, and the less is the smaller

portion on the opposite side. This disturbing element, though apparently minute, causes the centrifugal force slightly to increase with the spread, and is important enough, in the judgment of the exhibitors, to require the application of a spiral spring on the spindle, which is compressed in proportion as the balls ascend, and neutralises, by its increasing tension, the augmentation of the centrifugal force. The spring, they note, is useful also to neutralise the effects of inertia. M. Tresca has reported very fully and favourably upon this governor.*

Mr. C. T. Porter, New York, exhibited *two governors, for stationary and for marine engines.*

1. The *stationary governor* was employed on the stationary engine exhibited by Mr. Porter, to regulate the speed by acting upon the expansion-gear. The balls are very small, swing from a single joint, and revolve very fast, making from 300 to 350 revolutions per minute, with sufficient centrifugal force to enable them to sustain a "counterpoise" or sliding-weight fifteen to twenty times as heavy as the balls themselves. The counterpoise forms a part of the slide or

FIGS. 357.



MARINE GOVERNOR, by Mr. C. T. Porter, New York.

sleeve, and is linked to the balls by rods of the same length as the arms of the governor, forming, with the arms, a parallelogram. By this arrangement, the counterpoise has twice the vertical range of the balls, and Mr. Porter con-

siders that he materially reduces the friction on the various working joints—the principal cause of sluggishness of action in various ordinary governors,—and so increases the sensibility and promptness of action of the apparatus, and therefore improves the steadiness of the speed, tending to obviate the alternate variations of speed to which engines under common governors

* "Rapport sur le Modérateur à bras croisés, de MM. Farcot et Fils," addressed to the "Société d'Encouragement pour l'Industrie Nationale," 1861.

are subject. He conceives that he reduces the frictional resistance to the action of the joints by this disposition of the revolving masses,—the greater portion of which is located near to the axis of revolution, in virtue of which the centre of gyration is not more than two inches from the axis; whilst the joint-pin from which they are suspended is six inches long, measured diametrically across the spindle, presenting a leverage of 3 inches each way, for the action of the vertical spindle upon the balls, in accelerating or retarding their velocity. The long joint-pin, which prevents any wedging or binding action at the joints, arising from the lateral strain needfully exerted in retarding or accelerating the balls, is probably the chief novel element of importance in the governor; and there is no doubt that the governor acted promptly and efficiently.

2. The *marine governor* is like a common two-ball governor placed horizontally, with a helical spring on the spindle to act upon the balls, in substitution for the action of gravity. The governor makes from 300 to 500 revolutions per minute; and for readily changing the speed of the engine, conical pulleys are applied, upon which the driving-band may be shifted. The peculiarity of this governor consists in the nearly exact equilibrium that subsists between the resistance to compression of the spring and the centrifugal force of the balls at varying speeds—each increasing or diminishing as the other,—so that, at the regulated speed of the engine, the balls revolve almost indifferently in any circle of revolution, and a high degree of sensibility is attained. An increase of from 2 to 3 per cent. in the speed is sufficient to cause the play of the balls from one extreme to the other of their range, and so to entirely command the throttle-valve. In the adjustment of the governor, the spring is previously compressed just so much that its action only commences when the engine has got up to its proper speed (figs. 357, page 373).

Remarks.—It is to be observed that Miller's and Meriton's governors do not possess the qualifications of a complete regulator. In Meriton's, nothing is provided for reopening the valve after having been closed by the inertia of the fly-wheel; this must be done by hand. In Miller's, a spring or a weight is provided for that purpose; but it acts with a great deal of friction between the oblique acting surfaces, when strong enough to reopen the valve promptly. In neither of them is there any provision for balancing the momentum of the fly-wheel, like the vanes of Silver's governor, by the aid of which this governor can be made to regulate the speed of the engine within a certain number of revolutions per minute.

As the benefits of the application of an efficient marine governor are but imperfectly understood or acknowledged, it may be useful to direct attention, in the first place, to the

advantage of allowing the engineer, in a gale of wind and a rough sea, to attend properly to the working of the engines—which he must necessarily neglect if he is obliged to stand by the throttle-valve—without being able to move from his post, when he might otherwise cause a breakdown; and, though he may do his best, it is impossible for him to shut off and open the valve so promptly as it is done by the governor. The next point is the utter impossibility for the engines to race when the screw or the paddles get out of the water. At these times the engines properly governed do not exceed their usual number of revolutions by more than one or two per minute. The saving by preventing racing is acquired in different ways; during the racing of the engines the parts are often so overstrained that they break down, and the wear and tear is excessive. The saving of steam also is considerable, sometimes about 10 per cent. in a heavy gale: all the revolutions made while the engines are racing and the screw out of water merely waste the steam without propelling the ship. The saving of time has, in some instances, amounted to a couple of days in a ten or eleven days' voyage.

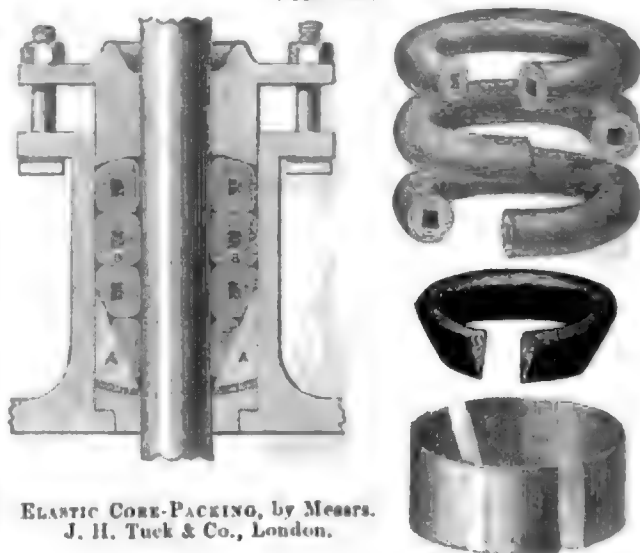
CHAPTER VIII.

SUNDRY PIECES.

Mr. J. W. Hackworth, Darlington, exhibited his *dynamic valve-gear*, in which the slide-valve is worked by an excentric, for the forward and the backward motion. The chief object is to open the valve quickly for the admission of steam; and Mr. Hackworth considers his motion more nearly fulfils the condition of mathematical accuracy than the link motion.

Messrs. J. H. Tuck & Co., London, exhibited *elastic core packing* for steam-engines, designed

FIGS. 358.



ELASTIC CORE-PACKING, by Messrs. J. H. Tuck & Co., London.

to obviate the objection of frequent removal required for hemp packing. It consists of a roll

of canvas prepared with india-rubber, with an elastic core. The roll is cut and bent into rings, and placed in the stuffing-box, which is fitted with a conical seat, upon which the packing is pressed by the gland, and is forced to embrace the rod (figs. 358).

Mr. F. Ransome exhibited a *concrete stone foundation*, manufactured for one of the horizontal steam-engines exhibited by Messrs. Ransomes & Sims in the Western Annex. The block, in one piece, weighed 2 tons. The concrete stone is composed of mineral fragments of any kind—sand, limestone, clay,—mixed into a paste with fluid silicate of soda (obtained by digesting flints in a steam boiler under high pressure in alkali), and afterwards dipped into a solution of chloride of calcium. The pasty mass almost immediately hardens, a double decomposition of the two solutions—the silicate and the chloride—immediately taking place. The silica combines with the calcium, and forms an insoluble silicate of lime, firmly enveloping and cementing together all the particles of sand, chalk, or other mineral of which the stone is composed, whilst the chlorine combines with the soda, and forms chloride of sodium or common salt, which is easily removed by subsequent washing. A bar of this stone, 4 inches square, was placed upon bearings 16 inches apart, and was reported by Professor Ansted to have sustained a load at the centre of 2,122 lb. ;

whilst a bar of Portland stone, of the same size, broke with 759½ lb. at the centre. A 4-inch cube of concrete stone sustained a weight of 30 tons before it was crushed. The specific gravity of the stone varies considerably ; that of the finest material averages 2,500, measuring about 15 cubic feet to the ton.

Messrs. J. Ferrabee & Co. (now the Phoenix Iron Works Company), Stroud, Gloucestershire, exhibited an *adjusting spanner*. The upper jaw of this spanner is formed with the bar extending the whole length of the spanner. The movable jaw, which slides on the bars of the upper one, has fixed to it on each side a metal rod, flat on one side, circular on the other. These rods are

FIG. 359.



ADJUSTING SPANNER, by the Phoenix Iron Works Company, Stroud.

screw-threaded at their ends, and they pass into a hollow handle, which is also screw-threaded inside, and is retained in its place by a collar screwed on the end of the bar of the upper jaw. They are quick and certain in action, light, and handy (fig. 359).

SECTION IV.

HYDRAULIC MACHINERY.

CHAPTER I.

INTRODUCTION.

As in 1851, so in 1862, the hydraulic machinery attracted a considerable degree of attention, and excited a considerable amount of discussion, with a considerable difference of opinion. In 1851, the jury upon hydraulic machines, in their report, entered with some degree of minuteness into the conditions to be observed in the forms and proportions of such machines, in order to realize the greatest degree of efficiency ; and they had occasion to remark that, "in reporting on the hydraulic machines exhibited, it was impossible to refrain from adverting to the general neglect of those elementary principles of scientific knowledge on which the perfection of such machines always depends, and, in some cases, their whole usefulness, in an economical point of view."* "Of

* The Jury referred to a fact not without interest in the history of the invention, and strikingly illustrative of the importance of other views of the principles of

all expedients," they add, "for the economical application of water-power, it is a principle that, as far as it may be possible, the water should be received on the machine without shock, and that it should leave it without velocity." Of

mechanics than were common among constructors in 1851, that the curved form of vanes [adopted in some of the American pumps] appeared to have been discarded for straight ones. Such inverted practice was supported by arguments like the following, quoted from the prospectus of the inventor of a centrifugal pump exhibited in 1851 :—

"In attempting to construct a centrifugal pump, a very large number of inventors have exhausted their skill in making arrangements of spiral or curved arms on an axle, or in endeavours to find the supposed angle or curve, with the diameter, which the fluid would make in passing off, being in utter ignorance of the fact, that in obedience to the law of central forces, the escaping fluid takes the shortest line to reach the circumference ; or, in other words, that each particle of matter in a state of rotation, when free to escape, moves directly in the line of the radius until it reaches the circumference, and thence follows the tangent-line, until influenced by gravity or some other disturbing force!"

Indeed, in our own day, in *The Engineer* newspaper of December 4, 1863, it has been actually supposed that "the proper outward motion of the water should be

the work done by the motive power to drive lifting and forcing pumps, M. Morin, in 1850, found that only 45 per cent. in the best, and 18 per cent. in the worst, pumps was found to be yielded, when the weight of water actually raised is multiplied by the height to which it is raised. In centrifugal pumps, as in turbines, the greatest efficiency is derived from the use of curved blades,—that is to say, with vanes curved backwards, with respect to the motion of the wheel, so as to have nearly the direction of a tangent to the circumference of the wheel at the point where they intersect it, so that the velocity of the water over the vane in one direction may be equal to that with which the vane itself is moving in the contrary direction. In proportion as these contrary motions become equal, the water leaves the machine without tangential velocity.

The centrifugal pumps exhibited in 1851 contained examples of straight and of curved blades, of which Mr. J. G. Appold exhibited his well-known pump with curved blades. Mr. J. S. Gwynne, of New York, exhibited a pump with straight radial parallel channels; and Mr. H. Bessemer exhibited a pump with radial arms and conical sides. These pumps were submitted to experiment by the jury, when the power expended was measured by a dynamometer, from which the pump-shaft was driven by a belt. The following remarkable results were obtained:—

PUMP.	GREATEST EFFICIENCY, in terms of the power actually applied to the pump-shaft.
	Per cent.
Mr. Appold's, with curved arms	68
Do. with straight arms, inclined at 45° ...	43
Do. with radial arms ...	24
Mr. Bessemer's, with radial arms and conical sides ...	22
Mr. Gwynne's, with straight parallel radial channels ...	19

From which it is apparent that the curved blade was superior in efficiency to the straight blade in any of its forms. Mr. Gwynne's pump yielded only 19 per cent. of the power applied to it; he, nevertheless, asserted that it was capable of doing a duty equal to 90 per cent. of the driving power.*

In 1862, the pumps of Mr. Appold and Mr. Gwynne have again been exhibited respectively by Messrs. Easton, Amos, & Sons, London, and Messrs. Gwynne & Co., London. The Author made several observations and experiments upon these pumps whilst at work in the Western

generated by nearly radial arms, falling back only near the periphery."

* See *Official Descriptive and Illustrated Catalogue of the Great Exhibition, 1851*, vol. iii., page 1441.

Annex, for his own information, and for the purpose, in addition, of finally settling and disposing of the stale question of curved *versus* straight blades. The results of these investigations are duly detailed in the following notices of those machines. They were, also, embodied in a report prepared by the Author to the order of the Admiralty, through Colonel Greene, the Director of Works. They point conclusively to the superior efficiency of the curved blades as originally designed by Mr. Appold, and constructed by Messrs. Easton, Amos, & Sons. It may be added that M. H. Tresca, sub-director of the Conservatoire des Arts et Métiers, and one of the jury on "Machinery in General," holds similar opinions of the relative values of the Appold pump and that exhibited by Messrs. Gwynne & Co. "Since 1851," he says, "the Gwynne pump has been considerably modified. It has imitated from the Appold pump the partial curvature now given to the vanes; and from experiments we have made upon the Gwynne pump, we believe that the imitation has not been carried far enough, and that the Appold pump maintains its superiority."*

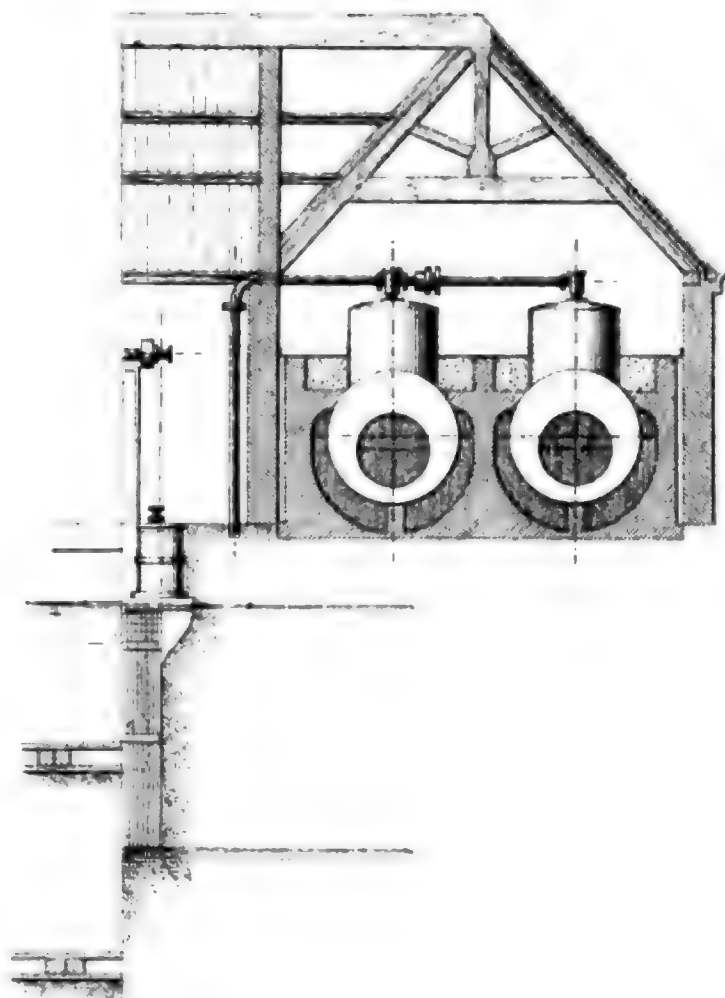
The centrifugal pump is probably the best adapted for extensive pumping operations, at low and moderate lifts of less than 20 feet. For higher lifts, of from 40 to 100 feet, Murray's chain-pump, exhibited by Mr. Middleton, appears to be the most useful machine. It is in general use for the purposes of the Main Drainage Works at present in progress in and near the metropolis.

CHAPTER II.

CENTRIFUGAL PUMPS.

Messrs. Easton, Amos, & Sons, London, exhibited a *centrifugal steam-pump* in action, driven by a pair of condensing engines, collectively of 40 nominal horse-power (Plate XXXVII). In consequence of the difficulty experienced in low districts of obtaining a solid foundation, the exhibitors devised this arrangement of steam-pump. It consists of an Appold pump on a vertical spindle, placed in a case or tank of cast iron, on the top of which are fixed two high-pressure expansive condensing steam-engines, giving motion to the spindle of the pump, by means of a bevil-gear fly-wheel working into a pinion. As arranged for exhibition, the water was raised by a pump 4 feet 7 inches in diameter from a cast-iron tank, 12 feet deep, partly sunk in the ground, containing 24,000 gallons, with a lift of about 6 feet (which is found to be the average difference of level of most drainages),

* *Annales du Conservatoire Impérial, 1862-63*, page 686.



STEAM ENGINES AND APPOLD PUMP.

used for Drainage purposes at

"ANNA REGINA", DEMERARA

BY

ASTON, AMOS, & SONS, LONDON.



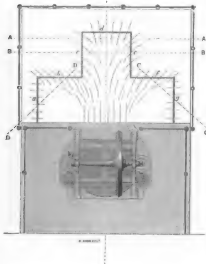
SCALE 1/16 INCH TO ONE FOOT

Day & Son, Lith^{rs} to the Queen

and was delivered over the edge of an upper tank back into the lower tank. The engines were worked expansively, cutting off at one-fourth of the stroke, and the water in the large tank was made use of to supply the condensers.

The two cylinders are placed upright, and are 20 inches in diameter, with 24 inches stroke, connected directly to the crank-shaft; and the condensers, the air-pump, and other connections are conveniently disposed and worked beside the cylinders (see fig. 360). The bevil-gear is in the

FIG. 360.



CENTRIFUGAL STEAM-PUMP, by Messrs. Easton, Amos, & Sons, London. (Plan of Pump and Tanks, showing the currents of water.)

ratio of about 2·4 to 1, or exactly as 124 to 52,—the pump making 124 revolutions for 52 revolutions of the engines. The water was raised from the lower tank, which was in free communication with the pump, into the well, 10 feet 3 inches in diameter, immediately above and surrounding the pump, whence it was delivered, through an opening at *k*, 6 feet wide, into the upper tank. The upper tank was built in the form of a cross, in plan, of ordinary tank-plates, with flanges 2½ inches broad on the upper edges, and it presented, for the overflow, seven such edges or weirs, *a, b, c, d, e, f, g*, each of them 6 feet, or about 6 feet, in length, presenting an aggregate length of weir of about 42 feet. The delivery of water from the well took place in the direction of the lines in the figure, and the water flowed steadily and unmixed with air, with an uninterrupted approaching velocity, over the edges *c, d, e*, and also over the edges *b* and *f* for more than half their length. Over the remainder of the edges *b* and *f*, the water fell with very little approaching velo-

city; and over the edges *a* and *g*, at the extreme right and left, it fell without any approaching velocity, having practically become still water. The directions of the currents, as they were actually observed, are indicated on the figure.

The Author's observations on this steam-pump were taken at various times in September, October, and November, 1862. They were directed, first, for the purpose of determining the quantity of water delivered over the weirs in a given time, as well as the height through which the water was elevated above the level of the water in the lower tank, in order to ascertain the duty, useful work, or performance of the pump; secondly, to determine, by means of the indicator, the actual power exerted by the engines to work the pump, in order to obtain a measure of efficiency.

To gauge the quantity of water discharged from the upper tank, a straight-edge was applied to the surface of the water flowing over the several frontages of the tank—not, of course, directly over the edges of the weirs, but at an interval sufficiently far behind them, where the water was level or nearly level, to give a direct measure of the depths of the approaching currents above the levels of the weirs. To gauge the current flowing over the edge *d*, the straight-edge was applied in the line *aa*; for the edges *c* and *e*, in the line *bb*; and for the edges *a, b, f, g*, in the lines *cc* and *dd*. The straight-edge was in every observation caused to lie thoroughly upon the water, so as steadily to intercept a sensible portion of the current. The head of water over the pump, at the well, was observed at two points, *h, i*, behind and before the pump-shaft. It was found to be greater behind the shaft, where the ascending water was partially accumulated; but the mean of the two observations has been adopted, for purposes of calculation, as the working head,—the head at the centre of the well;—though it remains, nevertheless, open for consideration, whether the head observed behind the shaft, at *h*, could not more properly be adopted as the working head. The following are the results of observations taken when the engines made 52 revolutions per minute, and the wheel 124 revolutions per minute:—

	Inches.
Head of water at the well above the level of the upper edge of the upper tank	12½
Depth of the overflowing current where it is level, or nearly so, near the front edge <i>d</i> ...	11
Do. do. near the flank edges <i>c</i> and <i>e</i>	10½
Do. do. near the flank and facing edges <i>a, b, f, g</i>	8½

Mr. Neville's table of discharges, calculated from the formula for still water,

$$D = 4.76 \sqrt{H^3},$$

embodying the co-efficient 0.617, was employed in the calculation of the discharge at the several

overflows, in which D is the quantity of water discharged in cubic feet per minute, l the length of the weir in feet, and h the height of the still water above the weir in inches. Allowance has been made for the effect of the approaching velocity of the water, due to the head, by means of this formula.* The interference of the internal angles of the weirs with the currents, is assumed to be compensated by that of the external angles. To find the discharge over the front edge d , that due to the head at the well, $12\frac{1}{2}$ inches, would be, by the formula, 210.564 cubic feet per minute per foot run of the edge; but the depth of current near the edge, 11 inches, having been $1\frac{1}{2}$ inches less than the head at the well, the discharge for $1\frac{1}{2}$ inches of water, namely, 8.753 cubic feet per minute per foot run, is to be deducted from that due to $12\frac{1}{2}$ inches of still water, and the remainder is the actual discharge per minute per foot run: thus, $210.564 - 8.753 = 201.811$ cubic feet; and this multiplied by 6.042 feet, the length of the edge, gives a discharge equal to 1219.3 cubic feet of water per minute over the front edge d .

Similarly, for the two flank edges, c and e , together 12.02 feet long, the united discharge is found to have been 2.369 cubic feet per minute; and for the two near halves of the facing edges b and f , together 6 feet long, the united discharge was 1034.69 cubic feet per minute. For the remaining halves of the facing edges b and f , together with the flanking edges a and g , without any calculation for approaching velocity, —in all 18 feet in length,—the discharge was 2125.3 cubic feet per minute. Making a total discharge from the upper tank amounting to 6748.3 cubic feet or $187\frac{3}{4}$ tons of water per minute.

The height from the level of the water in the lower tank, according to a glass gauge, to the upper edges or weirs of the upper tank, was 6 feet $0\frac{3}{4}$ inch. Adding half the depths of the currents near the different edges, as measured, the sums represent the mean useful heights to which the water was raised; and the heights multiplied by the respective quantities of water raised, represent the useful work done—the maximum work which could be done or given out again by the water raised, in falling back to the lower level. The average mean height is found by

* The Author here acknowledges the courtesy of Mr. John Neville, C.E., the hydraulic engineer, who, in company with the Author, closely observed the action of the pumps and the flow of the discharged water, and who advised with him as to the method and the formula for calculating the discharges, which the Author has applied to the observations made upon Messrs. Easton & Co.'s pump, and also to those made upon Messrs. Gwynne & Co.'s pump. Mr. Neville has written to the Author confirming him in selecting the formula for the discharge given in the text. He adds: "I have been very closely engaged, and have had no time to do more than glance over your letter. As far as I have observed, in doing so you seem to be quite right. . . . The comparison appears just, as far as I could observe without entering into the calculation."

this process to be 6.433 feet, and, the weight of a cubic foot of water being 62.32 lb., the useful work done by the steam-pump where it stood, is found to be equal to 82 horse-power; thus:—

$$6748.3 \times 62.32 \times 6.433 \div 33,000 = 82 \text{ horse-power.}$$

Simultaneously with the observations on the water discharged, the engine being steadily at work, indicator-diagrams were taken from both of the steam-cylinders, at both ends, by means of a Richards indicator. The annexed diagrams (fig. 361) are examples taken from the top and

FIG. 361.



INDICATOR-DIAGRAMS from the Steam-Pump of Messrs. Easton, Amos, & Sons.

bottom of one of the cylinders. The vacuum was as good as could be expected with the limited supply of water for condensation used over and over again, and made occasionally lukewarm. The effective mean pressure, averaged from a number of diagrams, was 28.3 lb. per square inch, and allowing for the sectional area of the piston-rod, the power exerted by the engine, making 52 revolutions per minute, amounted to 111.2 indicator horse-power. The useful work done, having been found to be equal to 82 horse-power, is equal to 73.74 per cent. of the indicator power exerted by the engine.

The total work done by the pump in the actual raising of water into and over the well, useful or otherwise, is found in terms of the lift, or the head in the well above the level of the water in the lower tank, which amounted to 6 feet $\frac{3}{4}$ inch + $12\frac{1}{2}$ inches = 7 feet $\frac{1}{4}$ inch. The lift being multiplied by the quantity of water raised, and reduced, the total work done is found to be 90 horse-power, or 81 per cent. of the indicator horse-power.

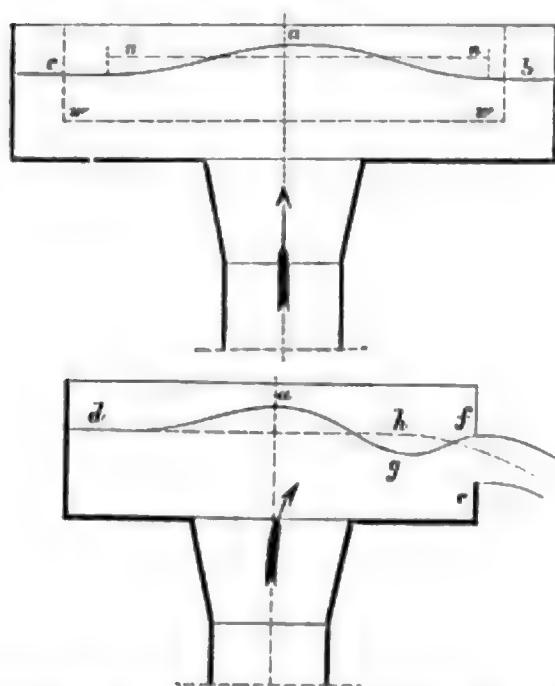
Messrs. Gwynne & Co., London, exhibited a *centrifugal steam-pump*, driven by a pair of direct-acting non-condensing horizontal engines. The pump had a wheel 4 feet in diameter, fitted with a number of blades formed straight and radial, or nearly so, towards the centre of the wheel, and partly curved backwards at the outer extremities, so as to form nearly a quarter of a circle. From this description it is obvious that Messrs. Gwynne & Co., in 1862, departed materially from the straight radial channels applied by Mr. Gwynne in 1851, and that they have likened the form of the blades to those of the Appold pump, exhibited in 1851, and reproduced in 1862,—so far at least as could well be done without adopting the Appold form in its entirety. It follows that the Gwynne pump of 1862 is an

improvement on that of 1851, though it remains considerably behind the Appold pump.

Messrs. Gwynne & Co.'s steam-pump consisted of a vertical wheel 4 feet in diameter, revolving within a case, on a horizontal axle, to which a pair of horizontal non-condensing engines were directly connected, with cylinders 18 inches in diameter, and of 14 inches stroke. The water, mixed with a great portion of air, was raised from a lower tank about 13 feet by 17 feet, through a large pipe 30 inches in diameter, into an upper tank, 12 feet by 9 feet, placed at a considerable elevation on four columns, from which the water overflowed at one side, in a frothy cataract, white with air-bubbles, as is permanently recorded in the photographs that were taken of the pump whilst in action; the water flowed over a weir 9 feet 8½ inches wide and ¾ inch thick, into the lower tank, where, owing to the great height of the fall, it churned the water and mixed a great deal of air with it, which was readily taken in by the pump, more particularly as the entrance to the pump was near to the surface of the water. The water, rising from the central pipe, rose above the surrounding level of the water in the tank in the form of a mound, and flowed off on all sides, but chiefly of course towards the weir, which it approached with a velocity greatest about the middle.

The condition of the water in the upper tank is illustrated by the annexed sectional figures

Figs. 362.



CENTRIFUGAL STEAM-PUMP, by Messrs. Gwynne & Co., London.
(Sections of the upper tank, showing the form of the central mound of water from the delivery-pipe, and the overflow.)

(figs. 362). The outline of the mound *a*, with myriads of air-bubbles mixed with it, was of double curvature, and it was about 8 feet 6 inches in diameter at its extreme base; it was surrounded by stationary level water at the sides *b*, *c*, and at the back *d*. The water flowing

towards the front was checked by the weir *e*, which stood square up from the bottom of the tank, about eight or ten inches high, and instead of being permitted to follow its natural course, as indicated by the dotted line *h*, the current rose again as it approached the weir, and made a second mound, of which the summit, at *f*, was precisely over the weir, and actually attained to the level of the stationary water, in the tank, leaving a considerable hollow, *g*, behind it. It is obvious, then, that the depth of water over the weir, at *f*, is not to be accepted as the normal depth, such as would legitimately carry the application of the usual formulas for calculating the discharge from this datum. It is an adventitious level, and signifies only that the device of the narrow square-edged weir, which was not in the original construction of the tank, increased the apparent effect of the pump, by partially obstructing and deepening the outflowing current.

Disregarding, then, the depth of the wave of obstruction over the weir *as*, in itself, an impracticable quantity, the level of the stationary water in the tank will be adopted for the approaching level of the overflow, to which the formula for discharge

$$D = 4.76 l \sqrt{h^3}$$

will be applied as in the case of the Appold pump. The approaching velocity of the water flowing from the central mound accelerates the discharge; but the acceleration mostly takes place at the middle of the weir. It is obvious that the influence of the maximum head of the mound extended over but a small portion of the weir; the width of the higher portions of the mound is very much less than that of the weir, and it, of course, spent its force to a considerable extent in sustaining the level of the stationary water. The mean height of the mound only, or half its whole height above the stationary water, will therefore be adopted as the mean head, for which the approaching velocity is to be estimated, and to be applied to the whole width of the weir.

According to the Author's experiments on Messrs. Gwynne & Co.'s pump, in November, 1862, to find the useful work done, the level of the approaching or the stationary water in the tank varied from 11 to 12½ inches above the level of the weir, but for present purposes take it at 12¼ inches; the maximum height of the mound above the level of the weir was 20½ inches, or 7½ inches above the stationary water; the mean head of water at the pipe or well over the pump, was 12½ + half of 7½ = 16⅞ inches above the level of the weir; the length of the weir was 9 feet 8½ inches, and the height of the edge of the weir above the level of the water in the lower tank was 18 feet 10½ inches, and the mean useful height to which the water was raised was 18 feet 10½ inches + 6¼ inches = 19 feet 4¼ inches. By Mr. Neville's tables, calculated by the formula already quoted, the discharge estimated for an approaching velocity relative

to the head over the well, as already estimated for the Appold pump, was 278·13 cubic feet of water per foot of weir per minute; and for the whole length of the weir 2703·2 cubic feet, or 75·2 tons of water per minute. The useful work of the pump, as it stood, was, therefore, 99 horse-power.

The engines exerted, according to the indicator-diagrams, of which one is shown in the annexed figure (363), an effective mean pressure of 26 lb. per

FIG. 363.



INDICATOR-DIAGRAMS, from Messrs. Gwynne & Co.'s Steam-Pump, after an alteration of the valves.

square inch, making 200 revolutions per minute; and they exerted $185\frac{1}{2}$ indicator horse-power. The useful work done, therefore, was equal to $53\frac{1}{2}$ per cent. of the indicator engine-power.

If the total work done in lifting water be calculated, say, to the maximum height of the central mound in the upper tank—though that is too high,—then the lift from the level of the water in the lower tank is 18 feet $10\frac{1}{2}$ inches + $20\frac{1}{8}$ inches = 20 feet $6\frac{5}{8}$ inches. The total work would be equal to 105-horse power, or $56\frac{1}{2}$ per cent. of the indicator engine-power.

In the preceding calculations of the work done by Messrs. Gwynne & Co.'s pump, no deduction has been made for the effect of the large quantity of air raised with the water drawn from the lower tank, which of course materially reduced the specific weight of the water operated upon. It is further to be remarked that the exhibitors, in their original application to Her Majesty's Commissioners, under-estimated the power required to work their pump, as they asked the Commissioners to provide for them only 85 indicator horse-power, whilst their pump actually consumed considerably more than double the amount of power applied for.*

* The extraordinary demand for steam to work Messrs. Gwynne & Co.'s pump was well known in the Western Annex. The power expended was at least 100 horse-power in excess of the requirements originally propounded by the exhibitors, and of course it occasionally overtasked the power of the boilers by which the steam was generated for supplying the Annex. The consumption of steam, moreover, was aggravated by the mal-proportions of the engine, as first arranged and worked during the greater part of the time the Exhibition was open, which caused a back pressure on the piston amounting to 40 per cent. of the whole pressure in the cylinder above that of the atmosphere. Later, by means of a slight alteration made in consequence of the Author's representations, the back pressure was reduced to about one-fourth of the positive pressure. The power really consumed within the cylinders, including that required to overcome the illegitimate back pressure, amounted in the gross to upwards of 260 horse-power, being 175 horse-power in excess of the 85 indicator horse-power that was

In forming an estimate of the comparative efficiency of the engines applied to the steam-pumps of Messrs. Easton, Amos, & Sons, and Messrs. Gwynne & Co.—respectively of the condensing and non-condensing kind,—it is to

sought by the exhibitors in their original application. In these facts one may find the origin of the difficulty that was occasionally experienced in providing steam of sufficient pressure for the legitimate requirements of the Western Annex.

A statement upon the comparative merits of the two steam-pumps has been made by Mr. Zerah Colburn, of New York, to the order of Messrs. Gwynne & Co., the exhibitors of one of the pumps. He commences by stating that "the trial of greatest interest was to ascertain the efficiency of the pump, both as to the absolute discharge and as to the proportion which the useful work done might bear to the power expended." Alluding to the central mound of water in the upper tank, he deducts 2 inches from its maximum height, to make "ample allowance for the somewhat inferior velocity of the water rising in contact with the inner surface of the pipe;" and he assumes that the height thus reduced "to a level 1 foot $6\frac{1}{2}$ inches above the crest of the weir" gives "the mean lift of the whole body of water as 20 feet $4\frac{1}{2}$ inches" above the level of the water in the lower tank. On what principle this "ample allowance" is made we are not informed; though it is clear that "the somewhat inferior velocity" referred to is not, as such, of any moment in estimating the mean head, which is a matter of direct measurement. The 30-inch delivery-pipe was expanded at its upper end into a square aperture through the bottom of the tank, about 3 feet square; and consequently the water quickly fell abroad on its delivery into the tank. If the pipe had been carried straight up to the tank, at 30 inches diameter, the water would no doubt have been raised to a greater maximum height, and probably Mr. Colburn would have deduced a still greater mean head, and calculated from that a still greater discharge than he has done, though the discharge must have been something less than before. The simple fact is, that the head and velocity of the spreading water, which disappeared on its getting into the upper tank, were more or less converted into pressure, and the effect was seen in the sustained level of the stationary water surrounding the mound. The mean head, as already stated, is determinable by simple measurement, without speculating upon inferior velocities at all.

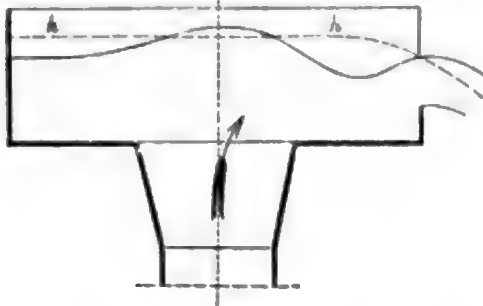
But an allowance of $4\frac{1}{2}$ inches of additional head is claimed by Mr. Colburn as a part of the "true duty" of the pump, in overcoming the resistance of the water in the pipe; whereas he professed that the trial of greatest interest was to ascertain the useful work done. Now, friction in the delivery-pipe is not useful work, nor is it a part of "true duty" either; for the delivery-pipe is an essential part of the concrete article called a high-lift pump, just as the large cast-iron well forms an essential part of the Appold steam-pump exhibited. He might as well have allowed for friction upon the wheel-case, and had better have stripped the wheel altogether, to try what it could perform without any inclosing friction-surfaces at all. Singularly enough, in an article in the *Engineer* of June 20, 1862, he estimated that the additional head due to friction in the pipe was equal to 2 feet, or about six times as much as he has more recently allowed! The truth is, the pumps had to be tried as they stood, and as integral portions of a system of conduits for conveying water from a lower to an upper level.

Mr. Colburn having estimated that the "corrected mean rise of the water above the crest of the weir" was 18 $\frac{1}{2}$ inches, he adds, that "it would be perhaps the least which, under the circumstances, would have been expected to give an overflow $12\frac{1}{2}$ inches thick on the weir itself;" that is to say, he assumes that, as $12\frac{1}{2}$

be remarked, that the employment of multiplying toothed gearing by the former, enabled them to work their engines at a moderate speed of piston and economically. Their engines cut off the steam at a pressure averaging $39\frac{1}{4}$ lb. per

inches depth of water at the weir is the depth due to an ordinary approaching level of about $18\frac{1}{2}$ inches, therefore there was a head equivalent to that of an approaching level of $18\frac{1}{2}$ inches over the whole length of the weir,—the same as if the tank had actually been filled up, in its length and breadth, to a uniform level of $18\frac{1}{2}$ inches. That this is not what would have been expected at all “under the circumstances,” and that the assumption is untenable, is manifest from the annexed section of the upper tank (fig. 364), showing

FIG. 364.



the actual conditions of the currents, and, in an additional dot-line *h h*, the fanciful conditions of a uniform high-level and regular overflow with which virtually Mr. Colburn seeks to identify the actual conditions. It has already been shown in the text, that the adventitious wave over the weir, $12\frac{1}{2}$ inches deep, is merely the effect of the surging of the shallow water descending from the mound against the square weir-board in front of it. That the mound is totally inadequate to such an exertion of head-pressure as is implied by a uniform high level, is plain, from the fact that it actually did not do so,—the level of the surrounding stationary water being $7\frac{1}{2}$ inches below the maximum height of the mound. If such an exertion of head as that belonging to a level of $18\frac{1}{2}$ inches above the weir was made, it must be asked,—Why did it not bring up the surrounding stationary water to that level? The head exerted by the mound was effective solely in accelerating the velocity of the central portions of the discharged current, which was nearly 10 feet wide, whilst the mound at its line of mean height was little more than 4 feet in width.

Here, then, is the mistake in Mr. Colburn's estimate of the performance of Messrs. Gwynne & Co.'s pump. “Taking the true head,” says he, “as 1 foot 6 inches, the full theoretical discharge without loss of any kind would be 5733·22 cubic feet per minute; and as the co-efficient to be applied in obtaining the actual discharge appears from a great number of experiments by many and high authorities to be ·57, the actual discharge would be 3,268 cubic feet per minute,” or 91·03 tons. This weight he takes as raised 20·73 feet high, which includes the head in the mound, with an additional allowance for friction in the pipes, from which he calculates an actual “duty” of 128·1 horse-power. It is singular that he, who, at the commencement of his report, professed the greatest interest in the “useful work done” should have included useless work in his calculations. He further calculates from the indicator-diagrams in his possession that the cylinders exerted an effective mean pressure of 26·66 lb. per square inch, which is equal to 192 indicator horse-power,—“the power expended in driving the pump.” Singular, again, that he should have professed the greatest interest in “the proportion which the useful work done might bear to the power expended,” and that, never-

theless, he should have omitted to ascertain the amount of the power expended. Instead of working out the indicator horse-power, and showing that, according to his own figures, the pump utilized only 66½ per cent. of the “actual power expended,” he attempts to form an estimate of the power delivered to the pump-shaft by a process for setting aside engine-resistance altogether, and, abandoning a certainty for an uncertainty, hypothetically concludes that the work done by the pump represented 83·18 per cent. “of the power actually applied in driving it!”

The test of a friction-brake, if there had been facilities for applying it to the pump-shaft, would, no doubt, have been desirable. At the same time, from a commercial point of view, it would not have been a final test, and the actual expenditure of steam-power in driving the steam-pumps was the real element on which the ultimate issues were dependent. Where, for example, would be the propriety of eliminating the engine-resistance from the indicator horse-power of a Cornish steam-pumping engine, and ignoring the total engine-power consumed in doing the work? But this is the sort of thing that Mr. Colburn has done. A steam-pump must have an engine, and doubtless the exhibitors considered their respective engines to be specially adapted for their respective duties; therefore, for straightforward commercial purposes, the total engine-power expended must needs be entertained for the purpose of comparison with the useful work done.

Mr. Colburn proceeds to inquire what may be the “absolute efficiency” of the Appold pump exhibited by Messrs. Easton, Amos, & Sons, “both as to the quantity of water raised and as to the proportion of useful work done to the power applied.” He has not admitted the element of approaching, or what he calls “initial” velocity, in his calculations of the discharge over the seven different edges or weirs of the upper tank, except only at the front edge (*d*, fig. 360). This is the great mistake in his treatment of the case of the Appold pump; for, in the first place, it was perfectly obvious to those who observed the flow of the currents from the engine platform, that the water rushed with an uninterrupted approaching velocity from the well and over the three foremost edges, front and flank (*c*, *d*, *e*), and likewise spread itself laterally over the facing edges *b*, *f*. Again, the tank had a depth of 3 feet, and its floor reached straight to the well, in addition to which there was another foot of water, in round numbers, above the level of the tank, emerging from the well into the tank,—making in all a square body of water 4 feet deep, and about 6 feet wide, delivered into the tank,—all of it moving, of course, with direct approaching velocity. This was an enormous entrance for a comparatively small tank. There was, then, no opportunity for the water to become stationary, except at the extreme sides *a* and *g*, where the observer could readily perceive that the water welled up, so to say, from the bottom of the tank; whilst the upper strata of the stream of water from the well rushed impetuously over the more advanced weirs, where the full force of the approaching velocity was inevitably expended. It might fairly be asked,—What became of that velocity, if it did not spend itself over the weirs?

In this, as in the case of Messrs. Gwynne & Co.'s pump, Mr. Colburn has omitted to quote the formulas by means of which he performs his calculations, which are involved in considerable obscurity, and encumbered with hypothetical allowances of various kinds. But that air, as is asserted by him, was intermixed with the water from the well of the Appold pump, was

has added 50 per cent. to the indicated consumption of steam at the point of cut-off, to represent the loss by partial condensation; and has estimated that, under the actual conditions, the condensing engines which worked the Appold pump used 2,475 lb. of water as steam per hour, which would require the consumption of about $2\frac{3}{4}$ lb. of coal per indicator horse-power per hour.

Messrs. Gwynne & Co., on the contrary, having coupled their cylinders directly to the pump-shaft, without the intervention of gearing, worked their pistons at a speed of 466 feet per minute, and steam was admitted to the cylinder during about 86 per cent. of the stroke. Without making any addition for loss of steam by condensation in the cylinders—less considerable, no doubt, than in the other engines,—it is estimated that they used about 9,776 lb. of water as steam per hour, which would require the consumption of about $6\frac{1}{4}$ lb. of coal per indicator horse-power.

In conformity with the foregoing particulars, it appears that the duties, or useful work done, of the steam-pumps, or pumping engines, were as follows:—

Messrs. Easton, Amos, & Sons' steam-pump raised 8,420 cubic feet, or 1,347 gallons, of water one foot high per pound of coal. Messrs. Gwynne & Co.'s steam-pump raised 2,570 cubic feet, or 411 gallons, of water one foot high per pound of coal. Showing that the duty of the steam-

not the case, as was obvious to any one who looked down into the well; and even if air had been drawn in by the pump, there was abundant freedom in the well, which was upwards of 10 feet diameter, for it to separate itself from the water before it entered the upper tank. Moreover, the discharge into the lower tank was delivered at a considerable distance from the entrance to the pump, where the water was comparatively still, and air was not likely to be found.

Mr. Colburn, then, by his defective mode of calculation, has estimated that 140·77 tons of water were discharged per minute, by the Appold pump, with a lift of 7·08 feet, which, by the way, includes useless work done, and is found by him to be the work of 67·68 horse-power.

In dealing with the indicator-diagrams taken from the Appold steam-pump, Mr. Colburn condemns those taken from the bottom of the cylinders as "nearly worthless," because they happen to be of less pressure and area than those from the upper ends of the cylinders, "on account of the length and comparatively small diameter of the pipe through which the steam was carried from the bottom of the cylinder to the indicator." "The pressure at the top of the cylinder has been taken as the true pressure [for the bottom], the engineman having stated that the slide-valves were carefully set to admit steam equally to the top and bottom of the cylinder."

Now, on referring to the indicator-diagrams (fig. 361, page 378), it appears that the valves were not equally set, inasmuch as they had not any lead at all at the lower ends of the cylinders; that is to say, the steam-port was not open at all for the admission of steam below the piston, at the commencement of the upward stroke. Moreover, the steam passage to the bottom of the cylinder was double the length of that to the top. Again, the piston travelled from the lower end

pump of Messrs. Easton, Amos, & Sons, per pound of coal consumed, was more than three times that of the steam-pump of Messrs. Gwynne & Co.

Messrs. Williamson Brothers exhibited a *centrifugal pump made with an exterior whirlpool*,—an addition introduced by Professor James Thomson, and reported to have increased the efficiency of the pump, compared with ordinary centrifugal pumps. The machine consists of a wheel or revolving fan, with an exterior case forming the whirlpool and outlet chambers. The wheel is constructed with a middle or partition plate, and two outer discs or covers with circular orifices for admitting the water at the centre on each side of the pump. Curved vanes are fixed between the middle and outer plates, extending from the central orifices to the outer circumference. The novelty consists in the addition of the exterior or whirlpool chamber round the circumference of the revolving wheel, which is usually made about double the diameter of the wheel. The water revolving in this round chamber assumes the condition of a "vortex or whirlpool of free mobility," the principles of motion in which were first noticed by Professor Thomson. The object of the whirlpool is to utilise the work contained in the rapid motion of the water on leaving the wheel. As the water passes from the centre of rotation, onwards, its velocity is gradually converted into or replaced by pressure,—in fact, the

than from the upper end; and, finally, even if all these circumstances had not existed, the length of the indicator-tube had little or nothing to do with the gross area of the diagram. It might, no doubt, have affected the true shape of the figure, but, inasmuch as the piston of the indicator travelled alternately up and down, in describing the figure, the pressure on the piston would, if affected at all by the tube, drag after the real pressure, and would be so described by the pencil, which would alternately describe the pressure in excess and in deficiency, as it fell and rose. These errors balancing each other, the area of the figure—the measure of force—would remain substantially correct.

It is clear, therefore, that there is no ground whatever for Mr. Colburn's hasty assertion of the worthlessness of the bottom diagrams. He has estimated that the engine exerted an effective mean pressure in the cylinder of 29·53 lb.; but, as before, instead of prosecuting the inquiry into one of the professed objects of interest—the power expended,—he proceeds to an attempt to eliminate a part of the power expended, namely, the friction of the engine; and concludes that the pump consumes 94·44 horse-power applied to the pump-shaft, abandoning, as before, a certainty for an uncertainty, and for no sufficient reason.

It is obvious that the writer of the statement which has thus been submitted to analysis, must have been unaware of the progress which has been made in the improvement of centrifugal pumps; and in particular of the indispensable necessity, now universally recognized and understood, of so constructing the machine, that the water should be received on it without shock, and that it should leave it without velocity, in order to attain the greatest degree of efficiency. It would appear, in short, that he is in error, not only in his data, but also in his arguments, and likewise in his conclusions.

force necessary to retard its velocity,—capable of causing it to ascend to a height corresponding to the energy deducted from its motion. This pressure is added to the outward force generated within the wheel. An outlet chamber is also provided, surrounding the whirlpool-chamber, to receive the water from all parts of the circumference of the whirlpool, and separated from it by conical discs designed to prevent any slowly moving or eddying water from breaking into and disturbing the whirlpool.

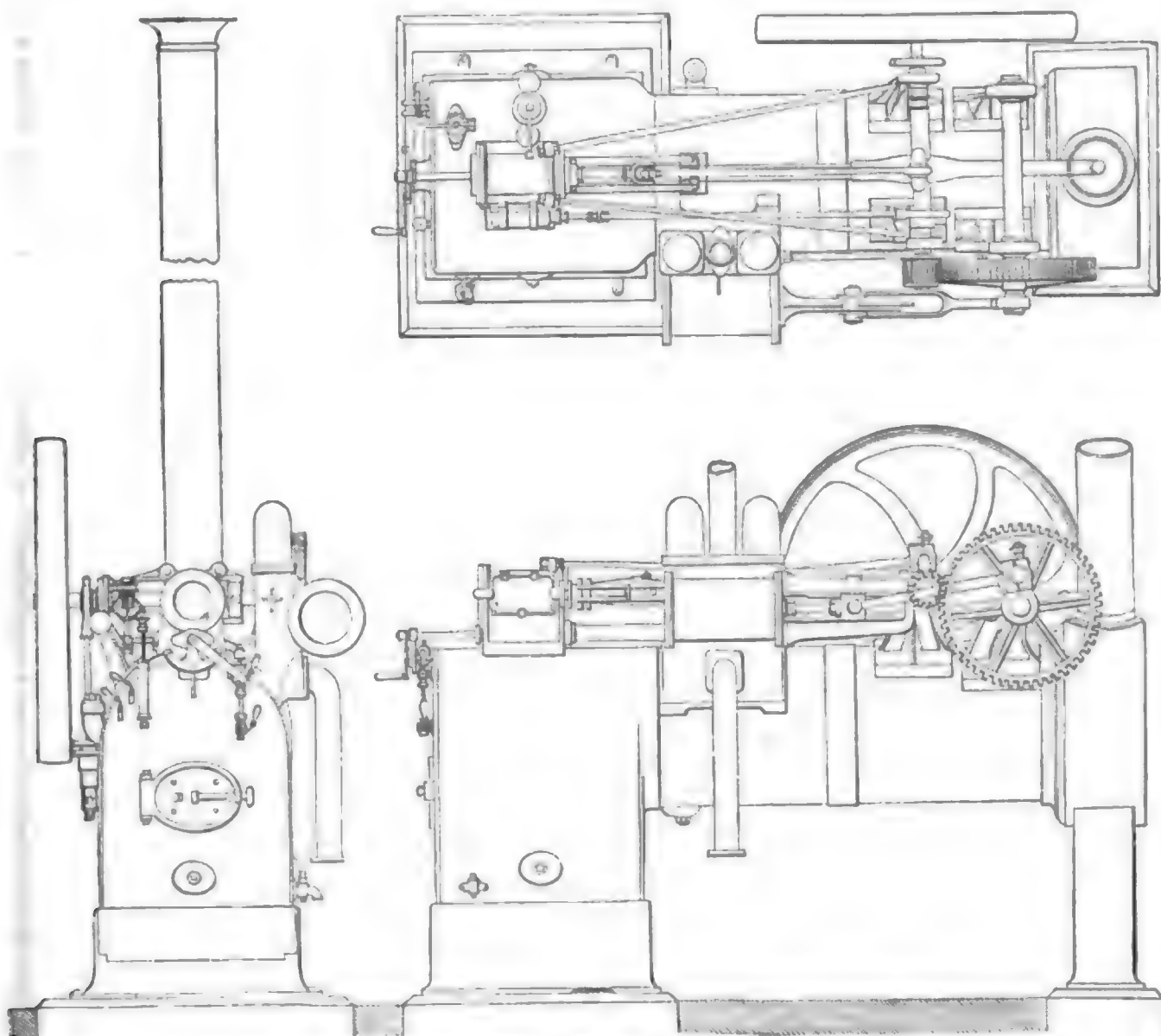
These pumps are specially designed for lifting large quantities of water through moderate heights, for purposes of drainage in low-lying districts, and for other purposes. Their efficiency is stated to amount to at least 70 per cent. of the dynametrical power applied to the pump-shaft.

CHAPTER III.

RECIPROCATING PUMPS.

Messrs. Ransomes & Sims, Ipswich, exhibited a *3-horse power steam-pump*, specially adapted for pumping water for fountains, railway stations, &c. The pump and engine are mounted upon a locomotive boiler, which rests on two cast-iron pedestals. The speed of the engine is reduced by gearing to suit the speed of the pump. The engine is said to be capable of raising from 4,000 to 5,000 cubic feet of water from a depth of 15 feet to a height of 100 feet in ten hours. The pump is lined with brass, the bucket is packed with leather, and the valves are of india-rubber seated on brass, and easily accessible (figs. 365).

FIGS. 365.



3-HORSE-POWER STEAM-PUMP, by Messrs. Ransomes & Sims, Ipswich.

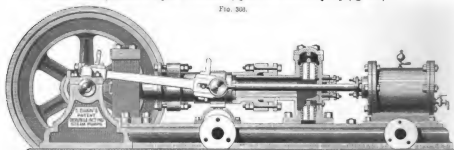
Messrs. Thomas Dunn & Co., Manchester, exhibited a *double-action steam-pump*, simply and compactly arranged on one base-plate, with one double barrel and two rams, in a horizontal line with the steam-cylinder, which is placed at one end, and a flywheel at the other end of the

base-plate. The rams are fixed to the bed, and the barrel is directly attached to and moved by the piston-rod, working upon the rams, and packed by a gland at each end, freely accessible, though it cannot be screwed up except when the pump is at rest. The upper valves

are readily got at by removing the cover, but not the under ones. The motion is transmitted to the crank-shaft by means of a pair of connect-

ing-rods, one from each side of the barrel. This pump is adapted for feeding boilers; it is proposed also as a fire-pump (fig. 366).

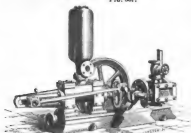
FIG. 366.



DOUBLE-ACTION STEAM-PUMP, by Messrs. THOMAS DUNN & CO., Manchester.

Messrs. DUNN & Co. exhibited also a *horizontal double-action donkey-pump*, the cylinder being at one end, and the pump at the other worked direct by the piston; the crank of the flywheel-shaft in the middle is worked by a slotted frame. There is a large air-vessel on the delivery-pipe, and the whole engine is light and compact (fig. 367).

FIG. 367.



DOUBLE-ACTION DONKEY-PUMP, by Messrs. DUNN & Co.

Messrs. Carrett, Marshall, & Co., Leeds, exhibited four varieties of *donkey-engines* or *steam-*

FIG. 368.



FIG. 369.



STEAM-PUMPS, by Messrs. Carrett, Marshall, & Co., Leeds.

pumps. Each of these has two air-vessels, one for the suction, and the other for the delivery, so that the water is drawn in and forced out in a continuous stream by the pump-ram, which is single-acting. Thus the working of the

FIG. 370.



STEAM-PUMP, by Messrs. Carrett, Marshall, & Co.

engine is independent of the distance from or to which the water may be fetched or forced, inasmuch as the water, being continuously in motion in the pipes in one direction, is not stopped and started at every stroke. In the first and second pumps (figs. 368 and 369) the flywheel is driven by means of a slotted-frame movement; and in the third (fig. 370) connecting-rods and slide-bars are used, as in ordinary steam-engines. The second pump (fig. 369) is used for working against great pressures, as in feeding locomotives, and is designed for pumping hot water. The

air-chambers are circular, and form the pillar-supports for the steam-cylinder. The fourth pump is like the third externally; it is a double-action pump on the bucket-and-ram principle, and has two clacks, delivering the water equally at the up and down strokes, and equalising the resistance—that is to say, the solid piston is worked by a rod of half the sectional area of the piston itself; during the up stroke the upper surface forces a volume of water into the ascending column, and the lower surface draws in twice that volume. In the down stroke, one of the volumes fills the space above the piston, and the other is sent into the rising tube. It is adapted as a complete pumping apparatus capable of delivering 10,000 gallons of water 150 feet high per hour, in one uniform stream. As a stationary fire-pump it has a working barrel $8\frac{1}{2}$ inches in diameter, with a 6-inch ram, having a stroke of 13 inches; the clack and piston are of brass.

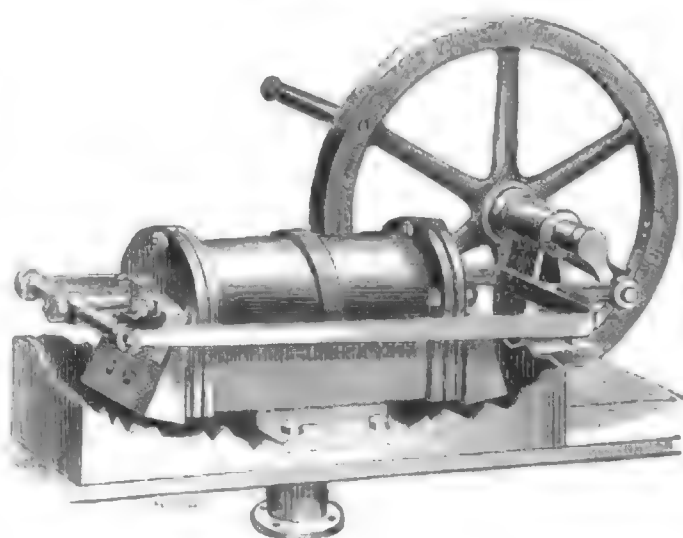
Messrs. Knowelden & Co., London, exhibited *Knowelden & Edward's diaphragm pump*, made with two single-acting barrels, worked by a double-vibrating lever. The barrels are fitted with elastic diaphragms across their bases, and are filled with water, covered by a film of oil up to the pistons; thus the pistons work out of contact with the liquid pumped, communication being entirely cut off, whilst they draw and force the liquid in the usual way. By this means the working barrels are preserved from the action of gritty, corrosive, or sewage water. The valves are hung in a cylindrical frame, which is readily withdrawn from the base of the pump for examination, and readily replaced.

Mr. J. L. Norton, London, exhibited a novel arrangement of *reciprocating pump*, dispensing with the ordinary barrel and piston, and having a horizontal trough of triangular section, into which the water is delivered through two alternate valves, hung in a diaphragm across the hollow of the trough; an inverted triangular trough encloses the suction-valves, and accurately fits and slides air-tight upon the diaphragm or frame which carries the valves. The two troughs together enclose a square space, and the delivery valves are hung one at each end of the reciprocating inverted trough, so as thoroughly to enclose the space between the troughs; it follows that when the reciprocating trough is traversed air-tight upon the fixed diaphragm, a vacuum is formed, and water is drawn into the pump, which is expelled through the reciprocating valves on the ends of the moving trough at the changes of stroke.

Mr. R. A. Godwin, London, exhibited the *Flood-pump*, having a horizontal working-barrel, with a reciprocating piston and a large outlet flap at each end. The water is brought up to the barrel from below through a T-shaped water-way, of which the cross-passage leads to

each end of the cylinder, and is fitted with suction-flaps, one to each end, as near to the end as may be, to allow for its working clear of the outlet-flap. The water discharged from the pump falls through the outlet-flap immediately on the reversal of the stroke. Access is had to the working parts by simply lifting up one or other of these flaps, by which stoppages in the pump may be easily corrected. The water-ways are large, and the whole of the contents of the cylinder, with sand, grit, or other matters that may be drawn in, are freely ejected at each stroke, so that no lodgment can be effected of matters usually fatal to ordinary horizontal pumps. The pump is fitted for forcing, by enclosing the tank in which it stands, and so converting it into an air-vessel (fig. 371).

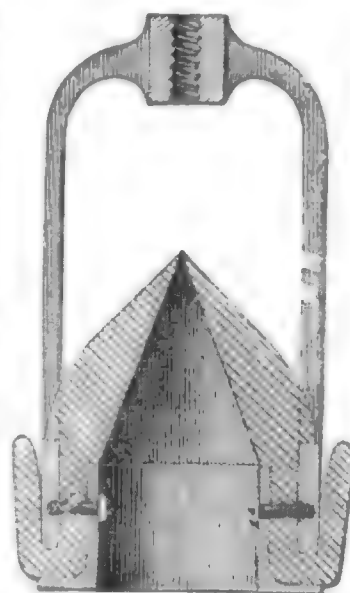
FIG. 371.



FLOOD-PUMP, by Mr. R. A. Godwin, London.

Mr. Perreaux, London, exhibited *india-rubber pump-valves*, of the form of a tube flattened at one end, like the mouthpiece of a clarinet. The thickness of the sides of the upper part diminishes gradually to the top, where the two sides meet and form two lips, which, when the valve is in a state of rest, are in close contact and prevent the downward passage of the fluid. With any upward pressure the lips separate and allow of the upward passage of the fluid. The gradual diminution in thickness or tapering of the sides forming the lips of the passage, enables the valve to open and close with the slightest variation of pressure, and, by

FIG. 372.



INDIA-RUBBER PUMP-VALVE, by Mr. Perreaux, London.

properly proportioning, to resist any required amount of downward pressure. The passage for the fluid is larger in these valves than in any others of equal dimensions; they also possess the advantage of having a "clear way," there being nothing whatever to retard the passage or flow of water, and they close perfectly and instantaneously the moment the pressure from below ceases (fig. 372).

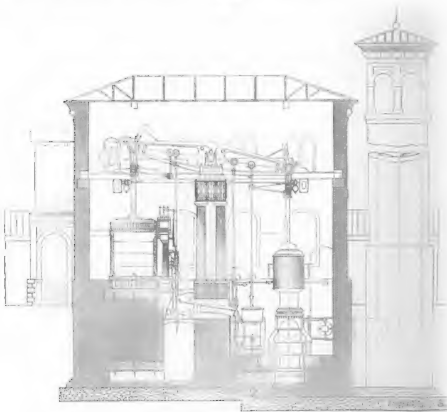
With one valve as a piston, and another as a suction-valve, a simple pump is obtained. But it may be remarked that with the resistance of the material, and the small dimensions of the orifices, an excess of motive-power is required, which may be an important element in large pumps. The durability of the valves must be

doubtful under hard work, as in the pumps of locomotive engines.

Mr. John Chedgley, London, exhibited a *glass pump*, having a bored and polished glass barrel, for pumping acid or alkaline fluids. Glass pumps are used in paper mills. A glass pump with 25 feet of glass pipe was exposed to the frost during the winter of 1860-61, and was frozen up several times, without any damage. The glass pipes have been tested to a pressure of 500 feet of water. Mr. Chedgley exhibited also *glass rollers* and glass beds for mangles.

Messrs. Harvey & Co., Hayle, Cornwall, exhibited a model of a *pumping engine*, for London water companies. The engine is of the well-known Cornish type, single-acting high-pressure,

FIG. 373.



PUMPING ENGINE, for London Water Companies, by Messrs. Harvey & Co., Hayle.

expansive and condensing. The accompanying illustration (fig. 373) represents one of the engines constructed for the East London Water-

works Company, and erected in 1855, at Lea bridge. At the time of its erection, this was the largest machine for supplying water to towns

hat had ever been constructed. The cylinder is 100 inches in diameter, with a working stroke of 11 feet. The pump is a plunger-pole 50 inches in diameter, with 11 feet stroke. The steam is in his engine cut off at an average of one-fourth of the stroke, Mr. Charles Greaves, the engineer of the East London Water-works, having found that a cut-off at one-fourth is a very convenient degree of expansion for regular working in such engines. The engine, when working full power, pumps about 9,000 gallons of water per minute, usually 40 feet high; and the water is conveyed into London by three cast-iron pipes 36 inches in diameter. The following account of the method of working the Cornish engines at the East London Water-works, is derived from a valuable paper read by Mr. Greaves before the Institution of Mechanical Engineers, at their meeting in London, in July 1862:—

“The steam is raised in cylindrical single-flued boilers, with internal fires to a pressure of 30 to 35 lb. per square inch above the atmosphere: the boilers are of ample dimensions, and not less than three are at work for each engine; they have large steam chests attached, and are all covered up with great care. The engines are worked at all speeds, which may be practically included between 4 strokes and 10 strokes per minute. The cylinders are all cased in steam-jackets, and these again are inclosed in an outer case filled to a thickness of not less than 12 inches, with very fine ashes. The cylinder-covers have no steam-jackets, but are well covered in various ways, as are also the steam-pipes and upper nozzles or valve-boxes. The steam-valves are in all cases double-beat gun-metal valves, and in as good order as close care and attention can maintain them. The boilers being filled with steam at 30 to 35 lb. pressure per square inch, the same pressure fills the steam-chest and steam-pipes up to the steam-valve. The supply for the steam-case of the cylinder is taken from the same boilers, and no difficulty exists in maintaining the full heat of the boiler in the steam case, amounting to 282° Fahr. with steam at 35 lb. per square inch above the atmosphere. The condensed water from the steam-case returns by gravitation to one of the working boilers, the cylinders being purposely set at such a level relatively to the boilers, as to allow of this continued circulation by mere gravitation, which is not interfered with by the working of the engine, continuing to act during the intervals of work or as long as steam remains in the boiler.

“The speed of the engine is regulated by an adjustable cataract: the exhaust-valve first, and then the steam-valve, are thrown open by treadle weights, as soon as the catches are detached by the cataract. The valves are closed, by tappets on a plug-rod: first, the steam-valve, and then the exhaust-valve, the former at a period of the stroke varying in practice between one-third and one-fifth from the commencement, and the latter at the end of the stroke. In engines

worked on this principle, as also in all reciprocating engines pumping without cranks, there is nothing to limit the strokes of the engine to any exact length. It is necessary, therefore, that bumpers or catch-pieces be provided to restrain the engine at both ends from an undue length of stroke; and thick plates of india-rubber under hardwood blocks are now used for this purpose in place of the spring-beams formerly employed. An engine thus arranged, working alone, lifting water from one fixed level to another, would work continuously with one length of stroke and one speed at whatever it might be set, but in waterworks with direct delivery,—that is, not pumping into a stand-pipe of constant height of column,—but where the levels of the reservoirs vary continually, and the velocity of the delivery into the main pipes is subject to continual fluctuation, it is found that a variation to the extent of some inches in the length of stroke results throughout the day; and the engines lengthen and shorten their strokes in obedience to the variable resisting pressure of the column of water. The variable resistance to the loaded plunger in the outdoor stroke causes the piston to stop at a variable distance from the top of the cylinder, a reduction in the resistance causing a greater velocity and a corresponding greater length of outdoor stroke, before the motion is completely arrested by the effect of closing the equilibrium-valve. An empirical dimension for length of stroke has consequently to be determined by observation as an average. Each stroke of these engines is an operation complete in itself, including within itself all the changes from rest to rest; and there is no momentum carried on, and no arrear of force subsequently supplied.

“The stroke of the engine raising the load, technically called the ‘indoor’ stroke, is performed in these engines at the mean velocity of from 500 to 600 feet per minute. When the steam is cut off at 1-4th of the stroke, a 10-foot stroke is frequently performed in one second, and an 11-foot stroke constantly in 1½ seconds, and when cut off at 1-3rd, the 10-foot stroke requires about 1½ seconds. This speed in pumping is almost peculiar to waterworks engines, for in mining engines the same length of stroke generally requires more than 2 or 2½ seconds. Much depends on this velocity. The chamber of the pump having to be filled during the indoor stroke, the dimensions of the suction-valves must be such that the least loss of power may be suffered in drawing the water in, and the adoption of double suction-valves has proved very beneficial in economising power. Moreover, as it is absolutely necessary for the good working of the engine that the suction-valves should be shut quite as soon as the engine concludes the indoor stroke, the lift and the loading of the valves are matters requiring considerable attention.

“For the purpose of obtaining a high duty,

Mr. Greaves's experience would lead him not to put a greater total load on the piston than about 16 lb. per square inch, including the friction of the engine, this total load being the total pressure on the piston measured by an indicator, and averaged over the whole length of the stroke. Now, in engines worked in the manner above described, at an average speed of about 7 strokes per minute, there is no difficulty in maintaining a vacuum in the condenser within $1\frac{3}{4}$ inches of mercury of the atmosphere at the time. Observations on this point have been made for years, from which is deduced an average of 1.66 inch below the atmospheric barometer at the time. Hence the average vacuum maintained in the condenser may safely be taken at 28 inches of mercury, or 13.75 lb. per square inch. This in action throughout the stroke leaves only the remainder, 2.25 lb. per square inch to be made up by the pressure of the steam, in order to balance the total load of 16 lb. per square inch on the piston, and therefore a somewhat greater pressure of steam than 2.25 lb. per square inch above the atmosphere, kept on the piston throughout the whole stroke, would produce motion. If, however, steam of a much higher pressure be admitted, the motive force will be greater than the load, and it will be necessary to stop the admission of the steam at some point before the end of the stroke, leaving the steam to expand through the remainder of the stroke, in order that the total power may not be in excess of the load to a greater extent than is necessary to produce the required speed of motion."

Messrs. Harvey & Co. also exhibited *Husband's safety-balance valve*, for pumping engines. It is fixed in, and forms a part of the main pipes for conveying the water, and by its action an engine retains its load in case the main should burst. It performs the office of a stand-pipe, and is intended to supersede that costly structure.

MM. Farcot & Sons, Port St. Ouen (Seine), exhibited a *force-pump*, in which the uniform motion of the water is obtained by means of two equal pistons, with valves affording very large water-ways, working parallel to each other in two pump-cylinders. During the successive strokes the first piston draws in water by its upper surface, and delivers it to the ascending column by causing it to traverse the second piston. In its ascending course the second piston raises in its turn the column of water by its upper face, whilst the lower face draws the water, causing it to traverse the first piston. This pump works well, and is adopted in the water-supply of Paris.

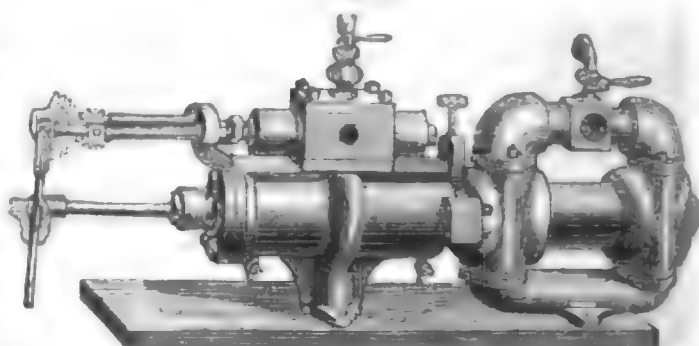
M. Letestu, Paris, exhibited some well-known pumps, as well as a double pump of large dimensions, for drainage purposes. A flexible water-pipe of leather is exhibited; it is 14 inches in diameter, and is fortified by curved

wrought-iron rings placed inside, kept in place by wire wrapped on the outside of the pipes in the intervals between the rings.

M. H. Hubert, Paris, exhibited two pairs of *force-pumps*, which were erected for supplying water to the two monumental fountains in the Horticultural Gardens. The barrels were horizontal, and were worked by over-neck cranks from a shaft driven by steam-engines. The connecting-rods were looped to pass alongside the barrels and to join the crossheads at the other end of the barrels. A great length of connecting-rod was thus obtained. The barrels were 10 inches in diameter, with 12 inches of stroke, and were designed to run at a speed of 50 revolutions per minute; but with the small orifices for suction and delivery of water, and the heavy cast-iron valves employed, they could not make more than 40 revolutions per minute, without endangering the pumps by concussions. A comparatively small air-vessel was fitted on the delivery-main for each pair of pumps, but there was nothing of the kind on the suction-pipes.

Mr. H. Steel, Jersey City, U.S., exhibited a *steam-pump* without a flywheel. It has only

FIG. 374.



TITAN STEAM-ENGINE, by Mr. Henry Steel, New Jersey, U.S.

one steam-cylinder and one pump; the slide-valve is brought into action instantaneously at each stroke of the piston by means of a small supplementary steam-piston very ingeniously disposed (fig. 374).

Mr. R. H. Worthington, New York, exhibited a *direct-action duplex pump*, composed of two steam-cylinders and two pumps, on two rods, each to each. The steam slide-valve is guided in each machine by the piston-rod of the other; by this means the movements are simultaneous in opposite directions with perfect regularity.

Mr. T. Hansbrow, California, exhibited the *California hand-pump*, which is compactly arranged, with a horizontal barrel fixed upon an upright standard, the piston of which derives its motion from an interior slide, working in guides under the barrel, and attached by an arm to the piston rod. The slide is moved by a handle and lever working in a slot in the guide. It is fitted with suction and delivery air-vessels, and possesses the peculiar features that it receives the water from above the barrel and is always charged.

CHAPTER IV.

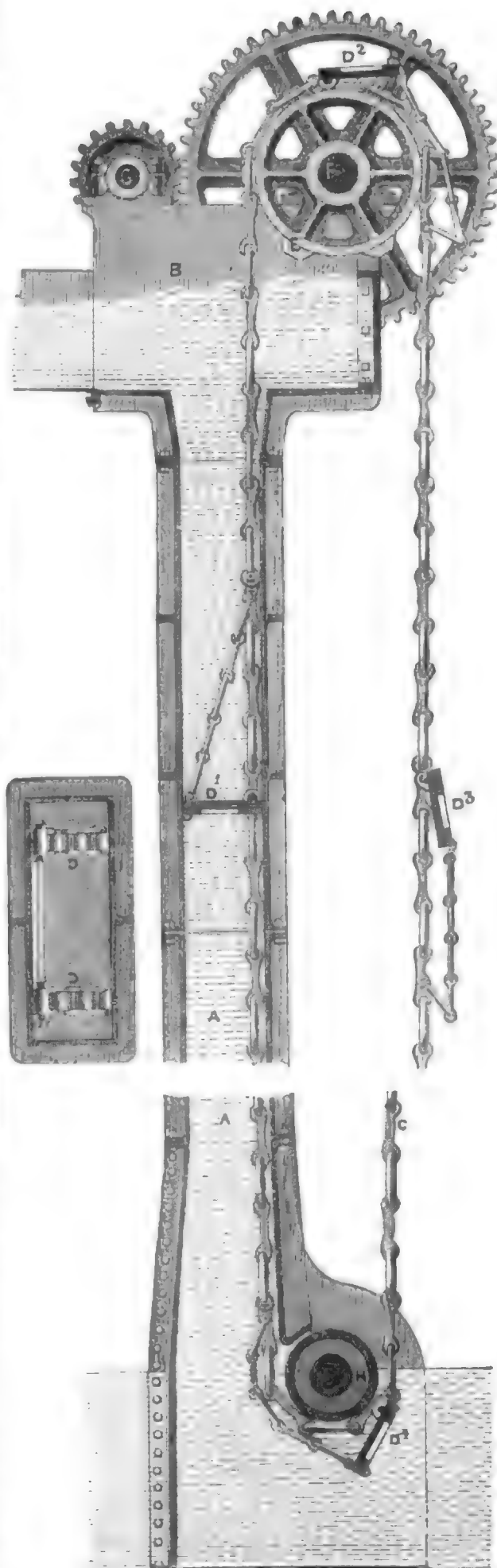
CHAIN-PUMPS.

The ordinary objections to the use of endless chain-pumps are the great space required for the head and foot-gear, the depth of water, the liability to choke, and the great number of lifts employed in their construction.

Mr. T. Middleton, London, exhibited *Murray's chain-pump*, in action, intended to obviate those objections. Frictional resistance is reduced by using only three or four lifts instead of twenty or thirty. The lifts are jointed to the chains, so as to settle at right angles to the ascending line of chain within the barrel. The chains pass under a roller at the foot, and are driven by a small pitch-wheel at the top over which they are conducted, and which are driven by appropriate gearing. The lifts feather in passing over the wheel, to the descending side, and only unfold when brought round to the ascending side; thus the pump is enabled to take off the water with the same dip as other pumps. The pump is not liable to be choked, as it may be freed from solid substances accidentally getting between the lift and the barrel; such substances can, by a back turn of the chain, be immediately released and carried up in the stream. The speed can be varied probably to a much greater degree than that of other pumps, without incurring the risk of breakage or derangement, whilst they do duty in proportion to the speed at which they are driven. As they have a continuous motion, and have no valves subject to get out of order, they do not require to be charged with water in order to obtain a vacuum.

The pump which is illustrated (fig. 375), has a lift 45 feet high, the barrel is 30 inches by 10 inches in horizontal section, and is made of cast-iron plates, of which the joints are planed and bolted together. The chains and bearings are of wrought-iron, and are steeled, when necessary, to resist the action of grit or sand washed up on the working parts. The chains are of great strength, and are fitted with lifts at about 10 feet apart. The ordinary speed of the chain for this size of pump is 200 feet per minute; but it may be increased to 300 feet per minute, as at the Crossness Pumping Station, Erith Marshes, on the Main-Drainage Works, where two such pumps are employed. The quantity of water lifted at the ordinary speed—200 feet per minute—is said to be about 2,200 gallons per minute; the pump-shaft makes about thirty-three revolutions per minute, and is driven by a toothed wheel and pinion, in the proportion of $3\frac{1}{2}$ to 1, a half-pully 3 feet 4 inches in diameter being fixed on the pinion-shaft, and driven by a belt from the engine. Each pump is driven by a horizontal engine of 30-horse power, having an 18-inch cylinder, with a 3-foot stroke, making thirty revolutions per minute, with steam of 32 lb. pressure per inch in the boiler. Another

FIG. 375.



MURRAY'S CHAIN-PUMP, by Mr. T. Middleton, London.

such pump has worked for two years at the Deptford Pumping Station, without having received any repair.

Two chain-pumps, with barrels 5 feet long by 15 inches wide, have been at work in Sweden since the year 1859, in the reclaiming of land, and have raised from 20,000 to 22,000 gallons per minute, 10 feet high, with a 70-horse power engine.

The greatest lift yet made by Murray's chain-pump has been 60 feet high; and it is considered that 100 tons of water per minute could be lifted 100 feet high. The greatest pitch or distance apart, of the lifts upon the chain that has been practised, is 12 feet. 10 to 12 feet of pitch has been found as efficient in performance as a shorter pitch, with more numerous lifts. According to the results of observations taken under Mr. Lovick's directions for the Metropolitan Board of Works, to ascertain the useful work done by Murray's chain-pump, the slip of the lifts, which work within the barrel, and are $\frac{1}{4}$ inch shorter each way than the dimensions of the barrel, for clearance, averaged 20 per cent. of their motion; and the useful work done averaged about 63 per cent. of the indicator horse-power of the engine.

Mr. J. U. Bastier, London, exhibited a *small chain-pump* in action. An ordinary endless chain is moved by a pitched wheel, and turned under a roller below. The pitched wheel was about 3 metres in circumference, pitched in three segments, coinciding with the pitch of the discs or lifts, which were one metre, or 3 feet 3 $\frac{1}{2}$ inches, apart on the chain. The discs are fitted with india-rubber washers which nearly fill, and slide smoothly within, the barrel, which is of glass-enamelled iron tube 4 $\frac{1}{2}$ inches in diameter. The lower part of the barrel is slightly contracted to allow the discs to pass with slight friction, and prevent all loss of water. This pump worked very well at the 9-feet lift to which it was applied, and with very little slip. It is not a bad pump for clear water and small bores, and would probably prove more efficient than a common pump. For large sizes it would not be likely to answer: the buckets would fall flat on the surface of the water to be lifted, as there is no provision for feathering them.

CHAPTER V.

TURBINES.

Professor W. J. Macquorne Rankine, Member of the Jury on "Machinery in General," reporting on prime movers, remarks that the "conditions to be fulfilled in order that the efficiency of a turbine, or water-wheel of any other kind, may be the greatest possible, are that the water shall begin to act on the wheel

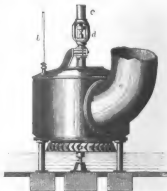
without shock, and shall leave it with no more velocity than is necessary in order to prevent the wheel from being choked with back-water."

"Turbines," he continues, "have been classed according to the general direction of the flow by which the water is carried through the wheel, independently of the whirling motion which is first impressed on the water by the guide-blades, and afterwards taken away during the action of the water on the wheel." The turbines exhibited, comprised examples of "outward-flow" turbines, in which the general flow of the water is from the axis; "parallel-flow" turbines, in which the general flow of the water is parallel to the axis; and of "an inward-flow" turbine, in which the general flow is toward the axis. "In order," adds Professor Rankine, "that the conditions of greatest efficiency may be fulfilled with different loads, the mode of varying the quantity of water supplied ought to be such as to change as little as possible the speed of the whirling component of its motion. This is effected in parallel-flow turbines by supplying the water through a ring of orifices, a greater or less number of which are completely closed when the supply is to be varied, so that all the orifices which are open are fully open. In the inward-flow turbine or "vortex-wheel," the same object is obtained by varying the obliquity of the guide-blades.

Messrs. Easton, Amos, & Sons, London, exhibited a *Fourneyron turbine*, outward-flow: it is compact and accessible, and contains a good regulating-gate, for controlling the supply of water, and a good method of suspension.

Messrs. Bryan Donkin & Co., London, exhibited a *parallel-flow turbine* suitable for a high

FIG. 376.



PARALLEL-FLOW TURBINE, by Messrs. Bryan Donkin & Co., London. *a*, revolving ring with buckets; *b*, rod from valve-tackle; *c*, upright shaft; *d*, bearing brass; *e*, supply pipe.

fall of water. The turbine consists of a revolving ring or bucket-wheel with descending curved vanes keyed on an upright shaft, which com-

municates the power; the weight is supported from a bearing above the surface of the water and easily accessible. The water is guided into the vanes of the revolving ring by curved vanes or guide-plates in a stationary ring, through which it descends and is directed upon the moving vanes in the direction of their motion, these vanes being so curved reversely as to receive the force of the water, which drops from them into the tail-water with little velocity. The turbine is reported to be capable of utilizing 75 or 76 per cent. of the whole power of the fall (fig. 376).

The North Moor Foundry Company, Oldham, exhibited horizontal and vertical *parallel-flow*

pose constructed in two rings, with reverse curvature, meeting at the middle, where the water enters, and is divided equally between them. In thus acting on both sides of the wheel, the water does not exert any pressure upon the footstep. The wheel also is cast hollow, and is made water-tight, so that it is partially floated by the water; and the balance of strains can be perfectly adjusted by suitably proportioning the divided currents of water between the upper and lower rings of buckets (fig. 377).

In the arrangement of the vertical turbine with a horizontal shaft, the water, as it leaves the wheel on both sides, is collected in a chamber—a casing which encloses the whole—from which it

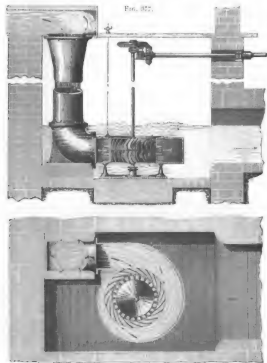
is taken to the tail-race by a pipe of the same diameter as the supply-pipe. If the tail-race be below the turbine, the vacuum or suction due to the difference of level adds to the effect of the pump, as if it were so much superincumbent pressure; and the turbine may be placed, without injuring its efficiency, at any part of the fall not exceeding 33 feet above the tail-water. In some instances the vertical turbines have been worked altogether by means of suction, being situated at the top of 30-feet falls. As the tail-water is discharged through a pipe of the same diameter as the supply-pipe, and must pass off with the same velocity as that with which it approaches, a portion of the useful effect is sacrificed thereby.

Messrs. Richard Roberts & Co., London, exhibited a drawing and a model of a *high-pressure balanced turbine* with parallel flow, in which the admission of water takes place from below. The upward action of the water thus balances the weight of the turbine.

MM. Fontaine & Bault, Chartres, exhibited the *Fontaine turbine* (parallel flow), in which the water is received from above, and discharged below the wheel. The supply of water is regulated by means of two sheets of gutta-percha, which are rolled or unrolled upon two cones on opposite sides of the machine, over the openings for the admission of

water to the fixed guide plates, so as to regulate the number to be open according to the supply of water.

Messrs. Williamson Brothers, Kendal, exhibited a *vortex or inward-flow turbine* at work on a fall of 8 feet. The vortex-wheel is made with radiating vanes, and is surrounded by an annular case, closed externally, and open internally to the wheel, having its inner circumference fitted with four curved guide-passages. The water is admitted by one or more pipes to



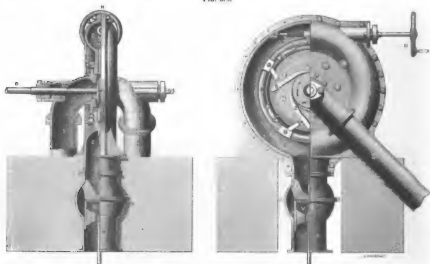
PARALLEL-FLOW TURBINE, by the North Moor Foundry Company, Oldham.

turbines, which are novel and ingenious. To the horizontal turbine, with a vertical shaft, the water is conducted by a pipe into a spiral water-chamber surrounding the wheel, from which it is guided through the water-ports horizontally on to the middle of the circumference of the wheel, so as to enter the curved wings or buckets without any shock, and after traversing them it passes off vertically, or nearly so, on both sides of the wheel, above and below, to the tail-race. The buckets are for this pur-

the case, and issues centripetally through the guide-passages upon the circumference of the

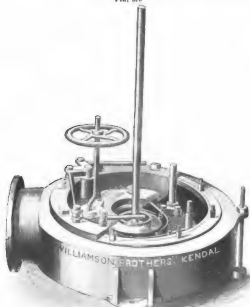
wheel; the water acting against the vanes of the wheel, the wheel is driven round at a velocity

FIG. 378.



VORTEX OR INWARD-FLOW TURBINE, by Messrs. Williamson Brothers, Kendal.

FIG. 379.



VORTEX-TURBINE. (Perspective View.)

dependent on the weight of the fall, and the water having expended its force passes towards and out at the centre.

The guide-blades are pivoted near their points, and are moved on these by means of a system of cranks and links, so as to widen or narrow the four passages simultaneously and

FIG. 380.



GUIDE-BLADES for the Vortex-Turbine, in detail.

equally. When there is a maximum supply of water, the guide-blades are opened to their full extent, and the water flows into the wheel round its entire circumference with the velocity at which the outer circumference of the wheel is moving, and without change of direction, and therefore without loss from impact or shock. With a less supply of water, the orifices are contracted by collapsing or moving the guide-blades towards each other, so that the reduced quantity

of water enters the wheel without any reduction of its velocity, and, in all cases, round the

entire circumference. Literally, the motion of the water is not exactly tangential, but spiral, and may be resolved into two components, one of them tangential and the other radial. The radial movement is very small, and the proper circumferential speed of the wheel is almost the same as the actual velocity with which the water enters, or that due to half the fall. The centrifugal force in the wheel arising from this velocity, is balanced by the contrary fluid pressure due to the other half of the fall, so that only one-half of the work due to the fall is employed in communicating *vis viva* to the water, to be afterwards taken from it during its passage through the wheel, the remainder of the work being communicated directly through the fluid pressure to the wheel. By this arrangement the velocity of the water when it moves fastest in the machine is very much reduced, compared with other turbines, and the loss due to the retarding action of channels or passages is diminished.

According to the results of a series of experiments for ascertaining the efficiency of the vortex, published in Mr. Fairbairn's "Mills and Mill-work,"—although they were made with a supply of water considerably below the standard quantity, and with a vortex in its ordinary working condition,—an efficiency of 77·55 per cent. was obtained when running at its proper speed.

The vortex-turbine, illustrated by the annexed figures (figs. 378, 379, 380), was constructed for a fall of 250 feet, and was designed to give 70 horse-power at the standard opening of the guide-blades. To obtain the unusually high fall of 250 feet, it has been necessary to convey the water, for a distance of about a mile, in open timber troughing, placed almost on a level, and from this it is carried to the vortex by iron pipes of 18 inches in diameter, and about 700 feet in length. The water is admitted at the lower side of the vortex-case, in order that the supply-pipe may pass under the floor of the mill, and thus be entirely out of the way, occupying no useful space in the building. For convenience in the application of the power, the vortex is placed vertically, and stands within the building upon a foundation consisting simply of two large stones; the water is taken from the wheel by suction-pipes, which pass at an angle through the mill floor into the tail-race, and the portion of the fall behind the wheel is thus rendered available. At the entrance from the supply-pipe to the vortex is an equilibrium sluice-valve, for shutting off the water. The shaft, on which the revolving wheel is keyed, being horizontal, the power is transmitted from it by spur-wheels to the main shaft of the mill, and thence it is applied to the machinery by belts and pulleys in the usual way. The vortex-shaft is carried through a stuffing-box on the side of a suction-pipe. The vortex-wheel makes 1,125 revolutions per minute. In consequence of the

extremely high velocity with which the water moves, the fall being so great, through the guide-passages and channels of the wheel, it is important that these parts should be free from the slightest roughness—such as might arise from corrosion if constructed of iron. For this reason all the parts where the water has a high velocity—the guide-blade chamber, guide-blades, and revolving wheel—are made of brass. The vanes are of *rolled* brass, as it is needful that they should be very thin. P is the supply-pipe, which conveys the water to the vortex. V, the equilibrium-valve, by which the wheel is started or stopped. C, the outer or supply chamber of the vortex, which is of large size, so that the water may pass from the pipe at a low velocity to the guide-passages. G, G, are the guide-blades, four in number; these form four passages, which converge from the entrance to the point of discharge, so that the water very gradually increases its velocity until it attains its maximum speed as it enters the wheel, where its direction is nearly tangential. R is an iron ring, to which the outer ends of the guide-blades are attached by links; the guide-blades fit accurately between the upper and lower sides of the chamber, but are made movable upon gudgeons near their points. By means of the hand-wheel, H, working a screw within the case, the ring can be made partially to revolve, and thus to move the four guide-blades simultaneously, and to open or contract the orifices at their points, to suit varying quantities of water. Whatever the quantity of water used, it always leaves the guide-passages at the narrowest part, and with the full pressure and velocity required for the greatest effect. W is the revolving wheel, which is keyed upon the driving-shaft, D. The water is discharged at each side of the wheel, and passes through the suction-pipes, S S, into the tail-race. A portion of the wheel is represented on a larger scale (fig. 380) to show the curvature of the vanes. Alternate vanes are made shorter than the others, so that the passages towards the inner circumference, where there is necessarily less space than at the outside, may not be unduly contracted.

CHAPTER VI.

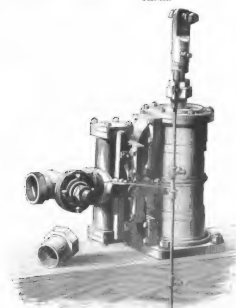
WATER-PRESSURE ENGINES AND HYDRAULIC RAMS.

Sir W. G. Armstrong & Co., Newcastle-on-Tyne, exhibited *water-pressure engines* capable of working or standing still at intervals without waste of power or water. This is effected by an accumulator, being a cylinder like that of an hydraulic press, having a plunger loaded according to the pressure to be maintained. One of the engines has a cylinder and piston of long stroke for working a hydraulic crane through pulleys and chain-tackle; another is for producing rotatory motion at high speeds with

three oscillating cylinders working on cranks at 120° with each other. "Relief-checks" are fitted to the cylinder, which, when the pressure is excessive, relieve the cylinder, and, when deficient, permit the water to flow back into the cylinder from the discharge-pipe, and thus prevent shocks without wasting water. The hydraulic crane is further noticed in a following chapter on cranes, section VI.

Messrs. Carrett, Marshall, & Co, Leeds, exhibited *Joy's hydraulic organ-blower*, consisting of a reciprocating water-engine, with a steady noiseless action. The mode of action is similar to that, already described, of *Joy's steam-hammer* (*ante*, page 201). The machine is of brass, with a 2-inch cylinder, and 5 inches stroke. The motion of the piston allows the water alternately to actuate the slide-valve after the piston completes its stroke. The stroke and the speed can be regulated with nicety (fig. 381).

FIG. 381.



JOY'S HYDRAULIC ORGAN-BLOWER, by Messrs. Carrett, Marshall, & Co., Leeds.

These machines may be constructed of great power, and are said to be capable of working under any pressure, and at any speed from 1 to 110 feet of piston per minute; and they are applicable to various purposes.

Mr. E. O. Richard, Canada, exhibited a *water-wheel*, which is a kind of rotary water pressure engine.

The different hydraulic rams do not exhibit any new arrangement, except that of MM.

Bollée & Son, Mans (Sarthe), in which a check-valve is adopted analogous to double-seated valves, by which the intensity of the shock is diminished; the pump feeding the air-reservoir set in movement by the play of the ram, but always situated above the level of the highest waters, works even whilst the ram is under water, which allows it to be placed in such a manner as to profit by all the height of the fall. The valve is counterpoised at will by a regulator, by means of which the velocity of the machine is governed.

CHAPTER VII.

HYDRAULIC PRESSES.

The hydraulic presses exhibited by Messrs. Hughes & Kimber, by Messrs. Peel, Williams, & Peel, and by Messrs. Samuelson & Co., have already been described (see pages 246, 264, and 266).

Mr. F. O. Ward, London, exhibited a system of *double-acting steam hydraulic pumps*, comprising some novelties and simplifications. On a hollow bed, serving also as a cistern, he groups a horizontal steam-engine and pumps, thus compressing two machines into the space of one. The pumps are peculiarly constructed to avoid accumulation of air. They are also of thrice the usual length, and coupled in pairs by a novel arrangement, allowing all four to be driven by two connecting-rods. That their threefold length may not involve diminished directness of thrust, the connecting-rods are proportionately lengthened. Thus twelve pumps with their twelve sets of valves are replaced by four, and twelve connecting-rods by two. This cheapened construction implies less cost of maintenance, and less "back slip." The power is transmitted by pinion and spur-wheel. These are all points of advantage, but it is desirable to isolate the steam-cylinder from the cistern, in order to avoid cooling the steam (fig. 382).

Messrs. E. T. Bellhouse & Co., Manchester, exhibited a set of *four hydraulic pumps*, worked by a combined steam-engine, on a diagonal frame, and intermediate spur-wheel, to reduce the speed. Also, *stop and let-off cocks*, worked by a hand-lever, by which the pressure may be put on or taken off instantly.

Messrs. Hayward Tyler & Co., London, exhibited a drawing of a *hydraulic press for expressing tinctures*. The material to be pressed is placed in a box which stands upon the table of the press. The box is lined with perforated plates for the escape of the fluid, and is with its contents pressed upwards against the mallet suspended to the head of the press. The mallet



FIG. 10. A PORTABLE STEAM ENGINE OF THE EARLY TYPE.



FIG. 11. A BEAM STEAM ENGINE OF THE EARLY TYPE.

in the development of the steam engine, and the history of the steam engine, from the first attempts at the use of steam, to the present day, is a story of progress and improvement. The history of the steam engine is a story of progress and improvement, from the first attempts at the use of steam, to the present day, is a story of progress and improvement.

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FIG. 12.



FIG. 13. A BEAM STEAM ENGINE OF THE EARLY TYPE.

CHAPTER VIII.

FIRE-ENGINES.

The object of a fire-engine is to deliver a stream of water in a certain quantity upon a given point; and as the projection of a stream of water at a high velocity from the nozzle of the hose can only be effected by the exertion of a considerable degree of pressure within the engine, it is of great importance that the whole of the working parts coming in contact with the water should be thoroughly water-tight. It is further of importance that the current should be projected in a compact body—not wastefully dispersed by the resistance of the air. By dispersion, it may be delivered either wide or short of the mark.

The special jury appointed for fire-engines submitted several of those exhibited to trial. The distinctive feature in the trials conducted by the jury, as compared with previous experiments, was the measurement of the water after delivery, which was accomplished in the following manner:—"Water targets were constructed, consisting of hoods of canvas, with a circular opening of six feet, this space being considered

the utmost limit to which a jet can spread without being dissipated into spray, and so becoming useless when projected on a fire. These targets were elevated on a horizontal cross pole, which was raised to any required elevation on posts erected for the purpose. To each target was attached a tail or shoot, also of canvas, through which the water which struck inside the target was conducted into a gauged trough or tank which stood below, and in which the quantity delivered was read off from a graduated index. "Owing to the extreme clearness of the atmosphere, and the almost total absence of wind, the day selected for the trial of manual fire-engines proved in the highest degree favourable for the purpose. The barometer stood at 29.87 inches. The pressure of the wind was $\frac{3}{4}$ lb. per square foot.

Manual Fire-engines.—Thirty-seven English and six foreign manual fire-engines were exhibited by ten English and five foreign manufacturers.

Messrs. Merryweather & Son, London, exhibited two *brigade fire-engines*. The first had two 7-inch cylinders, with 8 inches stroke of piston. The stroke of the handles was 34 inches.

FIG. 385.



COUNTRY BRIGADE, OR MODEL PARISH FIRE-ENGINE, by Messrs. Merryweather & Son, London.

The suction-hose was 3 inches and the delivery-hose 2½ inches in diameter. An engine of identical proportions, constructed by the same exhibitors, and highly finished and ornamented, was also exhibited, as "Hodges' Testimonial," having been presented to Mr. Hodges, of Lambeth, captain of the well-known volunteer fire-brigade established and maintained by him, and bearing his name, by the inhabitants of Lambeth. The second, or country-brigade fire-engine, is of a smaller size, having 6-inch

cylinders. In all these engines, the valves and passages are arranged as nearly as possible in a direct line, that the water may flow unimpeded through the pumps; and no water is allowed to remain in the pumps when at rest, so that no danger is to be apprehended from the freezing of the water in frosty weather. The air-vessels are large, and an india-rubber ball containing air is introduced into them, so that the air can never be entirely driven out of the air-vessels (fig. 385).

Messrs. Shand & Mason (now Shand, Mason, & Co.), London, exhibited several sizes of *fire-engines*. The first is of the brigade pattern, having two 7-inch cylinders, with 8 inches stroke; suction-hose $2\frac{3}{4}$ inches, and delivery-hose $2\frac{1}{2}$ inches. Another was constructed on Captain

Fowke's military pattern, with 6-inch cylinders; and a third engine had 9-inch cylinders, with 8 inches of stroke.

The annexed table contains the principal dimensions of all the manual fire-engines submitted for trial.

PRINCIPAL DIMENSIONS OF THE MANUAL FIRE-ENGINES.

Number of Engine.	Name of Constructor and of Engine.	Diameter of Cylinders.	Stroke of Pistons.	Contents of Cylinders.	Stroke of Handles.	Diameter of Hose-Pipes.	
						Suction.	Delivery.
No.		Inches.	Inches.	Gallons.	Inches.	Inches.	Inches.
1	SHAND & MASON (Brigade pattern)	7	8	2.22	33½	2½	2½
2	MERRYWEATHER & SON (Brigade pattern)	7	8	2.22	34	3	2½
3	ROSE (Brigade pattern)	7	8.1	2.25	31½	3	2½
4	MERRYWEATHER & SON (Hodges' Testimonial) ...	7	8	2.22	34	3	2½
5	SHAND & MASON (Captain Fowke's Military Pattern).	6	8	1.63	42½	3	2½
6	MERRIWEATHER & SON (Country-Brigade Pattern)	6	8.2	1.67	31½	2½	2½
7	ROBERTS (Double-action)	9½	3.44	1.76	38	3	2½
8	BLINKHORN & Co. (Double-action)	7	8	2.22	36	3	2½
9	SHAND & MASON	9	8	3.68	34½	3½	2½
10	BROUGHTON COPPER COMPANY (Brigade Pattern)...	7	8.35	2.32	31½	3½	2½
11	LETESTU (French)	4.6	6.95	.835	30	3	2

The results of the trials showed, that of the whole body of water delivered from the engines through nozzles, estimated in terms of the capacity and speed of the pumps, the relative useful volume delivered for each of the pumps varied between the following limits:—

	Per cent.
No. 1, with $\frac{1}{2}$ -inch nozzles	53 to 84
No. 2, " "	35 to 80
No. 3, " "	66 to 75
No. 4, " "	58 to 59
No. 5, with $\frac{1}{2}$ -inch nozzle	82 to 93
No. 6, " "	75 to 86
No. 7, double-action (broke down)	
No. 8, { " " } { $\frac{1}{2}$ -inch nozzle, one experiment ...	73
No. 9, with 1-inch nozzle	72 to 77
No. 10, " $\frac{1}{2}$ -inch "	63 to 70
No. 11, " $\frac{1}{8}$ -inch "	39 to 67

Steam Fire-engines.—The first land steam fire-engine was constructed by Mr. John Braithwaite, in 1829. It was shortly afterwards followed by a smaller one, which made its first public appearance at the large fire in London, when the Argyle Rooms were burnt down, and worked uninterruptedly for five hours. Several other steam fire-engines have since been constructed at different times.

The chief difficulty in the working of steam fire-engines has been the great length of time

required for raising the steam. The efforts of inventors and constructors for their improvement have therefore been directed chiefly upon the boiler, and with success.

Messrs. Merryweather & Son exhibited the only English steam fire-engine that was sent for exhibition—the *Deluge*,—comprising several new features. The boiler, designed by Mr. Edward Field, is particularly adapted for raising steam quickly. It consists of a number of copper tubes, suspended vertically from the roof of the fire-box, over the fire, closed at the lower ends, and open to the interior of the boiler at the upper ends. Within each tube a smaller tube is suspended, to conduct the downward current of water necessary to replace the steam formed in the outer tube. Thus an active circulation is induced within the tubes, so powerful, it is said, that three square feet of heating-surface is sufficient per horse power. In the free suspension of the tubes, also, provision is made for their free expansion and contraction. There is also an absence of priming in this boiler, and the accumulation of sediment in the tubes is prevented by the violence of the circulation, in virtue of which the sediment is carried up to the mud-jacket, from which it is blown off in the usual manner.

The *Deluge* is fitted with one 9-inch steam-cylinder, and one 6½-inch water-cylinder, placed horizontally, in direct connection, with a stroke of 15 inches. The engine has no fly-wheel, and the slide-valve is a piston-valve, worked for a portion of its travel by a lever connected to the piston-rod of the engine. The travel is completed by means of a coiled spring acting upon the valve, by the intervention of a double inclined plane and friction-roller, by which the steam-ports are quickly opened. The exhaust-port at one end is closed a little before the steam-port at the other end is closed, to form a cushion for receiving and bringing up the

steam-piston at the end of the stroke. Thus a uniform speed of piston is obtained,—uniform throughout the stroke; and a steady jet of water is delivered. The valves of the pump are so arranged, beneath the barrel, that grit and other foreign matter can neither injure the barrel itself, nor remain in the valve-box, and so that no water can remain in the valve-box when the pump is at rest. Consequently, the pump is free from danger from the freezing of water in it. The engine can be worked at any speed, of from 1 up to 200 revolutions per minute. The engine had a 5-inch suction-hose, and a 3-inch delivery-hose (fig. 386).

FIG. 386.



STEAM FIRE-ENGINE, by MESSRS. MERRYWEATHER & SOOS, LONDON.

This engine was tried at the *Serpentine* by the jury on fire-engines. By permission, two steam fire-engines constructed by Messrs. Shand & Mason, London, were likewise tried by them. The first and larger of the two had 8½-inch steam-cylinders and 7-inch water-cylinders, with a 9-inch stroke, horizontal, with a slotted cross-head, crank, and fly-wheel motion. The boiler was vertical, without flue-tubes, and of a conical form, to give a large area of grate. The base of the chimney, rising from the crown of the fire-box, was surrounded by water up to the point where it leaves the boiler, for

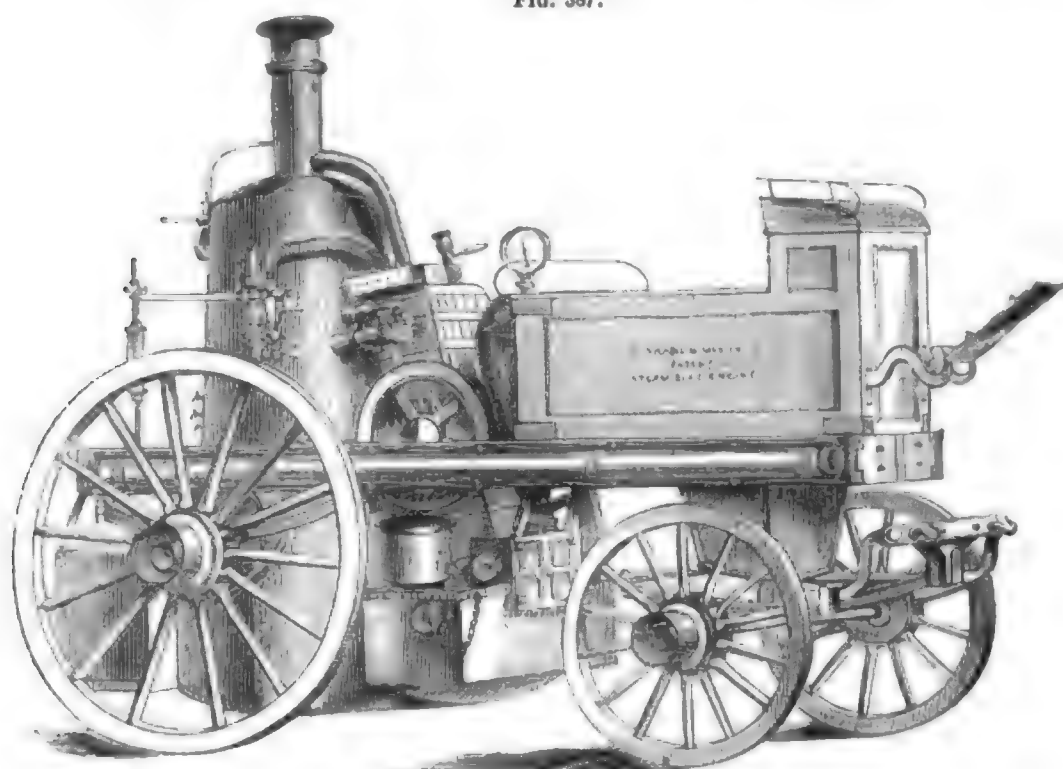
the purpose of adding to the limited heating surface of the fire-box. The suction and delivery hoses were 3½ inches in diameter. The smaller engine was similarly constructed, and had a 6½-inch steam-cylinder, and a 5-inch water-cylinder, with an 8-inch stroke. The suction-hose was 3 inches, and the delivery-hose 2½ inches in diameter (fig. 387).

Messrs. Lee & Larned, New York, exhibited a steam fire-engine, to be drawn by hand, and intended for the use of volunteer firemen. The engine is about 8 feet long, and weighs 3,700 lb. It runs on large wheels, and springs of fat

steel plates of uniform thickness, and tapered in width. The boiler contains double tubes, with an annular water-space between them, the flame and heat passing up through the inner

tube, and surrounding the outer tube. It is said to have 125 square feet of heating-surface, and to be capable of raising steam in seven minutes. The pump is of gun-metal, being

FIG. 387.



STEAM FIRE-ENGINE, by Messrs. Shand & Mason, London.

Cary's rotary pump, driven by a single reciprocating engine with a 7-inch cylinder, and 8½ inches stroke, and a pair of light balanced fly-wheels to carry the engine over the centre.

According to the results of the trials of the steam fire-engines, the following are the times in which the steam was got up from cold water, to 5 lb. and 100 lb. per square inch respectively :—

	To 5 lb.		To 100 lb.	
	min.	sec.	min.	sec.
Messrs. Merryweather & Son...	7	40	12	10
Messrs. Shand & Mason (No. 1)	12	50	18	30
Messrs. Shand & Mason (No. 2)	.....	...	30	0
Do. from warm water, the fire having been drawn and re-laid	5	30	17	40

The comparatively great length of time required to get up the pressure with Messrs. Shand & Mason's engine from cold water is reported to have arisen from some mismanagement; at the same time, allowing for this circumstance, it appears that the tubular boiler of Messrs. Merryweather's engine was the most prompt in getting up steam. The jury reported the following results of the trials of the steam fire-engines :—

"Messrs. Merryweather & Son have produced, at a price of £700, a steam fire-engine, weighing, according to the makers' account, 65 cwt., with jets and lamps, but without water, coal, suction-pipes, hose, or other gear, and capa-

ble of throwing in an available stream the following average quantities of water per minute :—

DISTANCE. Feet.	ANGLE. Degrees.	QUANTITY. Gallons.
61	10	230
85	21	124

"Messrs. Shand & Mason have produced an engine, at a cost of £650, weighing, according to their statement, 55 cwt., with jets and lamps, but without water, coal, suction-pipes, hose, or other gear, and capable of throwing in an available stream the following average quantities of water per minute :—

DISTANCE. Feet.	ANGLE. Degrees.	QUANTITY. Gallons.
61	10	250
63	18	165
82	14	172
85	21	137
102	11	94
104	17	19

"Messrs. Shand & Mason have also produced, at a price of £370, an engine which, under the same conditions, weighs 35 cwt., and is capable of throwing in an available stream the following average quantities per minute :—

DISTANCE. Feet.	ANGLE. Degrees.	QUANTITY. Gallons.
61	10	142
63	18	133
82	14	56
85	21	27

"The best performance during the five trials from which this last average was taken being

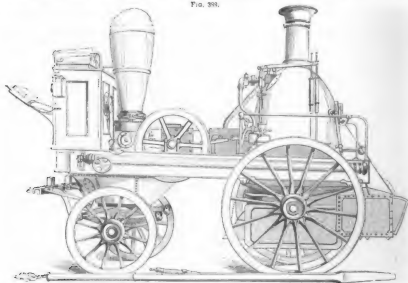
forty-six gallons, and the lowest five gallons per minute.

"At greater distances, in consequence of the wind, this engine could not deliver a stream, but continued working without accident through-

out the day, and concluded in the evening by throwing a good vertical jet."

Messrs. Shand & Mason have constructed an improved fire-engine (fig. 388) intended to combine the London fire-brigade engine with the use of

FIG. 388.



IMPROVED STEAM FIRE-ENGINE, by Messrs. Shand & Mason, London.

steam power, of which the following is a description:—"It is mounted on high wheels, springs, and forelocking carriage, and constructed for rapid transit by horses; is fitted with box to contain hose and implements, having driving-seat and space for firemen, and has poles on which to suspend the suction-pipes, thus carrying the firemen and all the hose and implements in or upon it. The extreme outside dimensions are as follows:—Length, 13 feet; width, 6 feet 5 inches; height, 9 feet without chimney. The total weight, including pole and bars for horses, hose-box, and driving-seat, suction-pipes, and coke-bunkers, is 6,099 lb.; weight of water, 400 lb.

"Like the London brigade engine, it can be primed with the suction-pipe, or water may be drawn from the cistern which forms part of the engine. The pumps are made entirely of gun-metal and copper, and the valves of india-rubber, as in the floating steam fire-engines made by Shand & Mason for the London Fire Brigade. The whole of the machinery is of a very simple construction, and not liable to be damaged by jolting over rough roads. The boiler is of the upright tubular construction, affording ample means for superheating the steam; there are 199 brass tubes $1\frac{1}{2}$ inch outside diameter and 15 inches long. The fire-box is of copper, 3 feet 4 inches diameter; the steam-cylinder is $8\frac{1}{2}$ inches

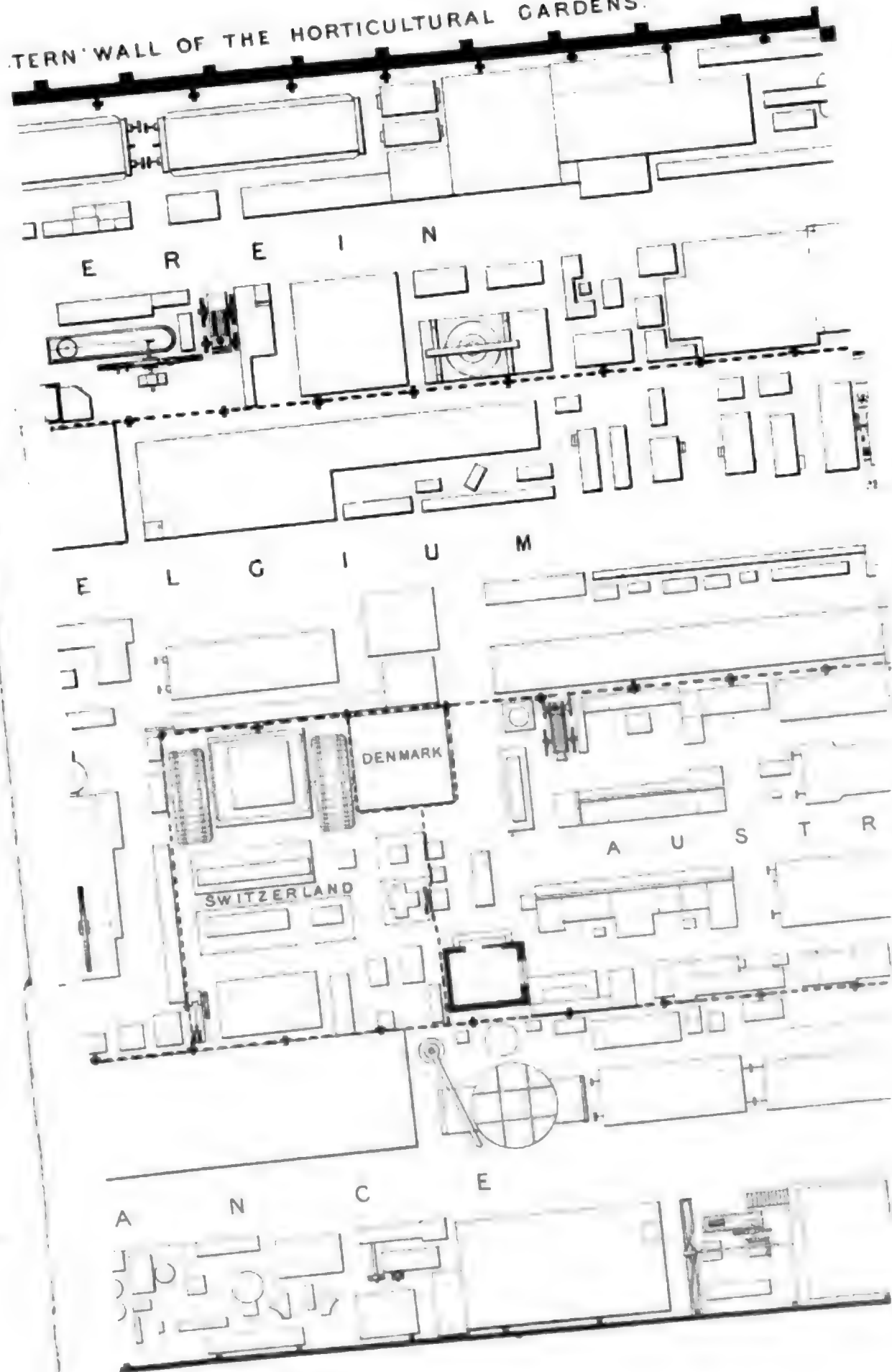
diameter, with 9-inch stroke; the water-cylinder is 7 inches diameter, with 9-inch stroke, and double-acting. The London brigade engines have pumps consisting of two single-acting cylinders, 7 inches diameter and 8 inch stroke. The average rate of working at fires is not more than 40 strokes per minute; and as the cylinders contain 616 cubic inches, it follows that a London brigade engine delivers, at its average rate of working, 88 gallons per minute. The water-cylinder of the steam fire-engine, as described above, discharges 690 cubic inches at each stroke, and as it can be worked at 180 strokes per minute, it will then be equal to five brigade engines at their ordinary rate of working."

Messrs. Merryweather & Sons have recently constructed the *Torrent* steam fire-engine, with a steel boiler. The steam-cylinder is $6\frac{1}{2}$ inches in diameter, and the pump, double-acting, has a $4\frac{1}{2}$ -inch cylinder, with a 12-inch stroke (fig. 389).

The double-barrel pump of Mr. Wellington Lee, of New York, for fire-engines, exhibited by Messrs. Easton, Amos, & Sons, in the Western Annex, has already been noticed. The following is a description of the *Amo-hilator* engine, on this principle, constructed by Messrs. Easton, Amos, & Sons (fig. 390):—

"The principal points in which this engine

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When these valves admit, steam from above, pressure is put upon the piston, causing motion forward, and when it is reversed, motion backward, being given.

and steam, connected by a short vertical rod, is admitted, causing it to move forward, and when it is reversed, it is

FIG. 100



FIG. 100. A STEAM LOCOMOTIVE, WITH A SINGLE CYLINDER.

When the piston is at the end of its stroke, the valve is closed, and the steam is cut off.

When the piston is at the end of its stroke, the valve is closed, and the steam is cut off.

FIG. 101



FIG. 101. A STEAM LOCOMOTIVE, WITH A DOUBLE CYLINDER.

When the piston is at the end of its stroke, the valve is closed, and the steam is cut off.

When the piston is at the end of its stroke, the valve is closed, and the steam is cut off.

the best Low Moor iron, are employed, with a view of obtaining the two essentials of lightness and compactness, in addition to the rapid generation of steam. Thirdly,—the steam cylinders are two in number, and are placed immediately forward of the boiler: their diameter is $9\frac{1}{2}$ inches, the length of stroke $9\frac{1}{2}$ inches, and they work directly on the pumps, without the intervention of any crank or rotary movement, and, consequently, any centre or dead point to turn. The piston-rod of one cylinder, by means of a reducing lever, operates upon the slide-valve of the other in such a manner, that when one piston is at the end of its stroke, the other is at half-stroke, and *vice versa*. This arrangement, while ensuring the correct action of the slides for the admission and exhaustion of steam to the cylinders, is not of itself alone sufficient to ensure the proper length of stroke; but to avoid the breaking of the piston or cylinder-cover, which might, perhaps, occur, two supplementary parts are provided, so arranged that the exhaust is imprisoned shortly before the termination of the stroke, and the piston starts smoothly and evenly on its return; and, however rapid may be the running, the motion is as certain and even as in two engines working with cranks at right angles upon one shaft. Fourthly,—the pumps are two in number, each $5\frac{1}{2}$ inches diameter; but the plungers and seats may be changed, in about twenty minutes, for others of larger diameter, in case a greater quantity of water may be required. The length of stroke is $9\frac{1}{2}$ inches, and, being double-acting, a steady and continuous stream is obtained from them. Each pump has eight suction and eight delivery valves of india-rubber, working upon gun-metal guards, offering an effective water-way of fifteen square inches, in four valves, or very nearly two-thirds area of the piston for the contents of one pump. The largeness of the valve-ways, combined with the peculiar stop at the end of each stroke, which is a main feature of the steam-valve motion, causes the almost instantaneous closing of the valves, and the pumps run free from concussion or vibration at any practicable velocity. The net area of the suction-opening is 16 square inches; and, having a continuous stream passing through it, the hose remains steady and quiet when the pumps are running at their highest velocity. Moreover, advantage is taken of the hollow spaces of the hand-railing to connect them with the suction-valve chamber, so as to form a suction air-vessel. All the suction and delivery-valves are readily accessible, by means of suitable hand-holes, and are not easily choked. Lastly,—the framing of the engine is of wrought-iron throughout, forged entire. Fisher's busk-springs, as offering the greatest elasticity and lightness, are employed, with relieving-screws for locking them out of gear when working. The wheels are of a construction embodying great strength and stiffness with

lightness; and wrought-iron rings and dowels are used for securing the spokes to the hubs. The engine, besides a moderate quantity of coal, and several hundred feet of hose, carries the following staff:—one driver, two look-out men, one on each foot-plate, and three assistants, who ride upon the tool-chest (which, when in position, forms a foot-board behind), standing themselves by the hand-railing. The net weight of the engine is 3 tons $2\frac{1}{2}$ cwt."

A number of trials of the foregoing steam fire-engines were conducted at Hodges' Distillery at various times during the year 1862, of which the following results were obtained, quoted from Lieutenant Becker's Annual Report of the proceedings of Hodges' Volunteer Fire-Brigade for 1863.

Messrs. Shand & Mason's improved fire-engine (fig. 388) got up steam to a pressure of 60 lb. per square inch in $14\frac{1}{2}$ minutes; and with a steam pressure of 120 lb. per inch, a jet of $1\frac{1}{4}$ inch in diameter was thrown to a height of 174 feet. A $\frac{7}{8}$ -inch jet was thrown horizontally a distance of 187 feet; a 1-inch jet 196 feet; a $1\frac{1}{4}$ -inch jet 190 feet. Strong wind.

Messrs. Merryweather & Son's engine, the *Deluge* (fig. 386), got up steam to a pressure of 40 lb. per inch in 10 minutes. With steam of 120 lb. pressure per inch, a $1\frac{1}{4}$ -inch jet was thrown 170 feet high, and 220 feet horizontally; and a $1\frac{1}{2}$ -inch jet 155 feet high, and 194 feet horizontally. Wind fresh.

The *Torrent* (fig. 389) got up the steam to a pressure of 75 lb. per square inch in 9 minutes, and to 100 lb. in $9\frac{1}{2}$ minutes. With steam of from 120 lb. to 140 lb. per inch, it delivered a 1-inch jet to a height of 150 feet, and to a distance horizontally of 194 feet.

The *Annihilator* (fig. 390) got up the steam to a pressure of 25 lb. per inch in 9 minutes. With a steam pressure of 120 lb. per inch, a $1\frac{1}{4}$ -inch jet was thrown to a height of 165 feet; and a $1\frac{1}{2}$ -inch jet to a height of 150 feet, with a steam pressure of 140 lb. per inch. A $1\frac{1}{2}$ -inch jet was thrown 197 feet horizontally; and a $1\frac{3}{4}$ -inch jet 190 feet horizontally.

CHAPTER IX.

WATER-METERS.

For upwards of 50 years, the desideratum of a good water-meter has engaged the attention of mechanical men. Joseph Bramah, in 1810, invented a water-meter on the principle of his rotary steam-engine, consisting of an excentric drum revolving within a cylinder, with protruding vanes or slides. More lately, Mr. Mitchell, of Glasgow, constructed a meter in which a spiral screw was placed within a pipe, to be turned by the current of water passing through

the pipe; the screw was fitted with resisting vanes to counteract the effect of varying velocities. A bucket-meter, also, was brought out by Mr. Stirling, of Dundee, but it proved unfit for practical purposes.

The earliest patent for the invention of a water-meter in England, was obtained in 1824 by William Pontifex, of London, and during the thirty years from 1824 to 1854, 42 patents were issued for water-meters. During the eight years ending in 1862, 78 more patents were obtained, making in all about 120 patents for water-meters, and improvements in them, during the last forty years. Of these, by far the larger number, about 44, have been constructed with diaphragms, flexible chambers, and similar appliances; 25 on the principle of the spiral fan, turbine, or drum; 16 with revolving buckets, floats, or oscillating chambers; and the remainder, about 35, with cylinder-and-piston motions. All the meters made with diaphragms or flexible measuring-chambers, have entirely failed, and fallen into desuetude,—the last example, rather clumsy, and scarcely original, by an engraver named Ramsbottom. Of the spiral fan, drum, and turbine meters, commonly known as inferential meters, the only one now in use is that invented by Mr. C. W. Siemens; all the others of this class having been abandoned as useless. Of the piston-meters, Kennedy's got into considerable use, although it was heavy, cumbersome, and noisy whilst working, with its large tumbling weight, which racked the apparatus by its continual vibration. But, with the liability of the weight to stick on the centre, and allow the water to pass unmeasured, and the frequent failure of the india-rubber piston-rings, with the regular oiling and packing required in addition, Kennedy's meter did not fulfil the requirements for a serviceable piston-meter. Messrs. Chadwick & Frost's meter is the latest of piston-meters, and it has got into considerable use in Lancashire and Yorkshire. Three other piston-meters have been introduced during the last seven or eight years by Mr. Jopling, Mr. T. Duncan, and Mr. Worthington. All of these, similar to each other, differ from Kennedy's and Chadwick & Frost's, chiefly in their having two cylinders, these having only one cylinder.

Mr. C. W. Siemens, London, exhibited his *water-meter* in its most improved form. The chief difficulty that presented itself in endeavouring to produce a practically perfect high-pressure meter was not so much to obtain a correct measurement under varying circumstances of pressure as to render the instrument sufficiently durable to resist for years the action of the water, and of the impurities carried along with it. It was found necessary to protect all the working parts against the chemical action of the water, to prevent deposit of calcareous matter upon the measuring apparatus, and to combine strength with lightness, as far as possible, in the

construction of the movable parts, in order that they might resist the force of a high water-column, and might yet be moved by the slender stream produced by a leaky tap, which in the case of the smaller meters, may not exceed half a pint of water passing through per minute. Cheapness and compactness of construction were other important considerations not to be lost sight of.

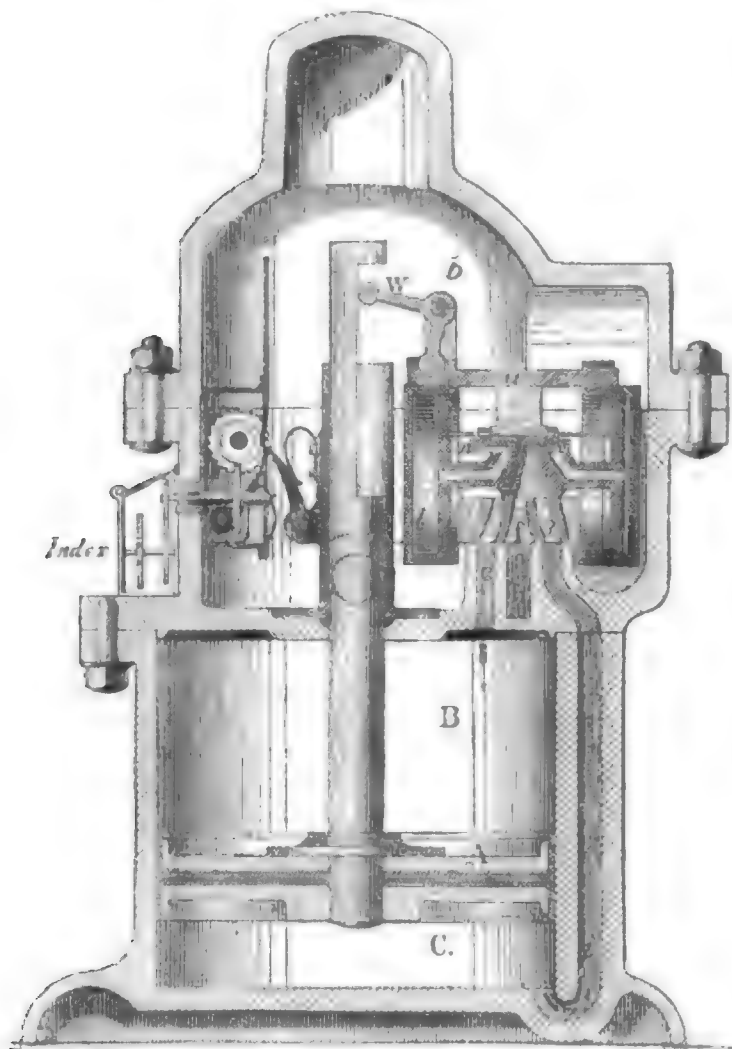
The meter consists of a cast-iron casing, divided by a partition into two compartments. The water entering the upper compartment passes through a spout into the revolving drum, which is formed of two stamped discs of brass plate, riveted and soldered together face to face, each part containing similar spiral grooves or corrugations, forming channels for the water to pass from the centre to the circumference into the lower chamber. The drum carries three or more flat blades, intended to produce a resistance in the water, increasing as the square of the velocity of revolution; the effect of which is, that the drum, which has a tendency to revolve at a rate increasing more rapidly than the velocity of the water, is caused to rotate at a speed proportionate to the quantity of water passing through, whether a high or low velocity.

The spindle of the drum passes upwards into an oil-chamber, which contains wheel-work, to reduce the motion communicated by the drum. A small spindle passes finally at a greatly-reduced speed through a stuffing-box into a fourth, containing the dial, on which the quantity of water that has passed through the meter is indicated by hands, in gallons or cubic feet. Before entering the meter, the water has to pass through a grating which arrests any solid matter, and is made easily accessible for the purpose of removing from time to time the impurities that have collected, when it is found that the passage of the water is obstructed.

Meters constructed on this plan have now been found to work continuously for nearly three years, under the most varied circumstances, without requiring any alteration whatever. The arrangement made between the manufacturers and the water companies or purchasers of the meters is, that every meter that fails to give satisfaction, in consequence of stoppage or inaccuracy of measurement, shall be exchanged; and experience shows that the number of meters so returned does not exceed $2\frac{1}{2}$ per cent. in the year, and these for the most part have been sent back only from trivial causes. It has been ascertained by experience, that when the drum was rotating at 2,000 revolutions per minute, only five or six revolutions were made by it after the discharge had been suddenly stopped; and the little error arising from this cause was nearly compensated for by the effect produced by the inertia of the drum at the commencement of motion, a small quantity of water having to pass through the drum not registered, before the drum had attained the velocity corresponding

with the velocity of the water through the meter. A meter had been used to measure the water supplied to an engine-boiler, and had been placed between the feed-pump and the boiler, and consequently the drum was set in motion and stopped at each stroke of the pump, and went with jerks; but even under this severe trial the meter was found to register only about 5 per cent. in excess.

FIG. 391.



CHADWICK & FROST'S WATER-METER, by the Manchester Water-Meter Company.

M. Tresca, of the *Conservatoire des Arts et Métiers*, Paris, has recently tested Mr. Siemens's meter, and he found that its indications were very nearly exact, even under great variations of pressure,—the maximum error of indication scarcely amounted to 1 per cent.

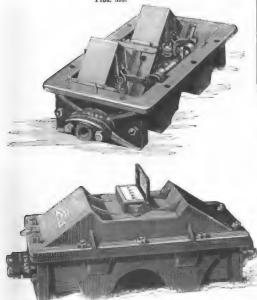
The smallest size, with a drum $1\frac{1}{2}$ inch in diameter, intended for a $\frac{1}{2}$ -inch pipe, registers a delivery of 5 gallons per minute. One of the largest sizes has an 8-inch drum, intended for a 10-inch main, and delivers 500 gallons per minute. They register within from $\frac{1}{4}$ to 3 per cent. under extreme conditions. The rapid currents of water through the passages of the drum prevent the deposit of calcareous matter in the passages, and thus the dimensions of these passages are preserved in their integrity. Mr.

Siemens's meter appears to fulfil all the conditions required of a serviceable meter, and to give satisfaction. There are at present above 10,000 of these water meters in action in England, besides which they are applied in Germany, Belgium, and France, exclusively. By a recent improvement in the details of construction, a meter of the smaller size can be made to register as small a stream as will just fill a tumbler in two minutes.

The Manchester Water-Meter Company exhibited three different kinds of *Chadwick & Frost's water-meters*. 1. A meter for general purposes, ordinarily used by water-works companies, measuring by a piston packed with cup-leather, and a brass-lined cylinder, with a compound slide-valve, reversed by a ball-crank which is struck by the piston-rod just before the completion of each stroke. Each stroke is registered by means of a pall and ratchet-wheel. "In the sectional illustration (fig. 391), the meter is shown working. The water is entering through the sieve or grating, the upper chamber of the meter *b*, and is passing down *c* into the measuring cylinder *B*: the pressure of the water being exerted in forcing the piston *A* to the bottom of the cylinder; the water is being expelled out of the lower part of the cylinder *B*, up *i* and *g*, down *f*, and out at *h*. On the completion of the stroke of the piston, the projecting end of the piston-rod carries with it the catch *W*, which moves the top slide-valve *n*, and removes the pressure from the small cylinder or cup *l*, and admits it into the opposite cylinder or cup, whereby the fluid pressure is exerted directly against the end of the main valve *J*, changes its position, and thus reverses the action of the meter instantaneously, and without noise or concussion." The meter is self-lubricating, as all the working parts are of brass, and are under water. The wear of the slide-valve, which is scraped on the faces, is limited to that due to the small difference of pressure on its upper and under surfaces. Should the meter get out of order and cease to work, the flow of water is stopped also. This, which is reckoned one of the advantages of the meter, is thought an objection by those who consider that the claims of the public to an uninterrupted supply of water are of greater moment than the loss to the water companies, in the event of a meter ceasing to register, and nevertheless continuing to pass the water. 2. The *office or dwelling-house meter*, by Mr. Frost,—the smallest meter that has yet been made with a piston and cylinder. "It consists of two measuring chambers, fitted with pistons, which are packed with cupped leathers, and a valve of a peculiar construction for

changing the inlet and outlet ports. The fluid acts directly against the rib or midfeather on the back of the valve-plate, and thus changes the position of the valve, and reverses the course of the fluid to be measured. On the termination of each stroke of the piston, and not till then, this change is completely effected. The working of the piston being slightly easier than that of the valve, it is necessarily carried to the end of its stroke before the valve is put into motion, and the minutest accuracy of measurement is thus insured." 3. The *steam-boiler or hot-water meter*, by Mr. Frost, without packing, which will work with warm water, for the filling of steam-boilers. It is composed of two pumps, formed each of a rectangular box, moving horizontally in the right angle or trough formed by two fixed planes. A partition, fixed perpen-

FIG. 392.



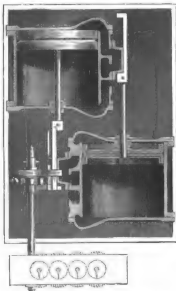
HOT-WATER METER, by the Manchester Water-Meter Company. (Two designs.)

dicularly to the intersection of the two planes, and filling the section of the box, performs the office of a fixed piston, and separates the two cavities of the box, which fill alternately as they are extended. The box slides in grooves adjusted on the fixed planes, each governing the slide-valve of the other (fig. 392).

Messrs. Thomas Lambert & Son, London, exhibited *Jopling's water-meter* in action. It is composed of two equal parallel cylinders, of which the pistons work together in the same direction, the piston-rod of each engine regulating at the extremity of the stroke the admission of the water into the neighbouring cylinder.

All the water must pass through one or the other of these two cylinders; and the number of oscillations registered measures the quantity

FIG. 393.



JOPLING'S WATER-METER, by Messrs. Thomas Lambert & Son, London.

of water which has passed. The cylinders are inclosed in a case of cast iron, so that the pressure is the same at the exterior as the interior of the cylinders, and its influence on the play of the machine is nearly annihilated. Thus, as the movement of one piston governs the supply of water to the cylinder of the other piston, a continuous current of water is established. The mechanism is simple, but there are four moving parts, the pistons and the valves (fig. 393).

Mr. Thomas Duncan, Liverpool, exhibited a *double-cylinder meter*, with cup-leather pistons. The piston-rods are attached to slotted cross-heads, coupled to cranks at right angles on a shaft. The slide-valves are of brass, working on brass faces, and are moved by eccentrics on the shaft. Thus a constant length of stroke is maintained, and the lap and lead are adjusted, and concussion is prevented, by slight portions of an arc cut out of the crosshead, permitting the piston to rest for an instant, until the valve is opened for water to reverse the piston. Upwards of sixty of these meters are said to be at work; the maximum error in their indications has not

exceeded 4 per cent., which is said to have arisen from the wearing of the pistons.

Mr. W. Dingwall, Dundee, exhibited a *water-meter*, in which the measurement is made within an oscillating elastic bag, within a cast-iron casing.

M. Sacré, Brussels, exhibited a *hydrometer* for distilleries. The liquid is measured as it leaves the still, at the same time that a small quantity of liquid, variable at pleasure, is preserved at each measuring, and conducted into a special receptacle, which allows of recording readily the mean density of the liquid distilled.

In making a comparison of the reaction meter, solely represented by Mr. Siemens's meter, with the piston-and-cylinder meter, the latter has naturally at first sight the advantage over the former, being, as the name implies, positive, whilst the other is inferential. But the distinction is scarcely tenable in practice, as neither the one nor the other is absolutely exact. The friction of the slides and other parts in the piston-meters, and the clearance at each end of the cylinder, are found to vary with the pressure and speed at which the machine is worked; except, of course, the clearance in Mr. Duncan's meter, of which the stroke is a fixed quantity, determined by the throw of the crank. The use of an upright and single cylinder in the meter of the Manchester Company makes it, no doubt, in so far, compact and simple, and diminishes the chance of injury from dirt or grit in the cylinder. The valve-gearing is complicated, and in this respect the double-cylinder meter of Mr. Jopling is simpler and better designed. But the drum-meter of Mr. Siemens obviously excels the others in simplicity, as it has positively no working parts besides the spindle on which it revolves; and since the addition of the vanes to the drum for the purpose of putting a check upon over-running, there is probably nothing more to be desired of Mr. Siemens's meter, as a useful, practical, and commercial instrument.

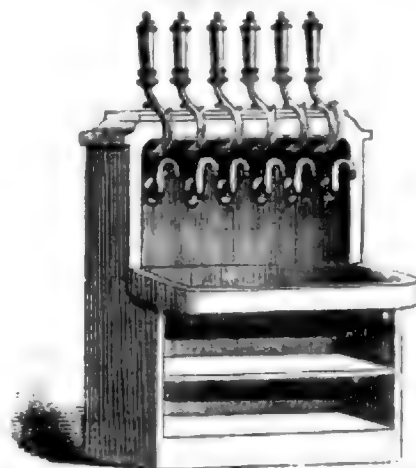
CHAPTER X.

BEER-ENGINES, ETC.

Messrs. Farrow & Jackson, London, exhibited a selection of apparatus for wines, spirits, and other fluids:—1. *Cellular wine-bins*, constructed of light bar-iron, with a separate rest for each bottle. 2. *Wrought-iron scantling*, for supporting casks. 3. *Bottling apparatus*, in which a trough is kept filled to a certain level by means of a cock with a float and valve, whence the liquor flows into the bottle through syphons, in so gentle a stream that no froth is caused. Several bottles may be filling at once, and precisely to the point required, on a level with the fluid in the trough, so that no inspection is required, and

they may be corked without being looked at—saving time and liquor. 4. *Corking machine*, having three conical tubes, for different sized bottles. The cork being placed in one of them is by means of a lever pressed directly into the neck of the bottle. No jarring or pressure upon the bottles takes place, so that they may be tightly corked without risk of breakage. 5. *Corking machine*, of the form most generally used by bottlers in London. The bottle is held in a leathern boot, strapped to the knee, and the cork, after being compressed by the machine, is driven into the bottle by a blow with a hardwood

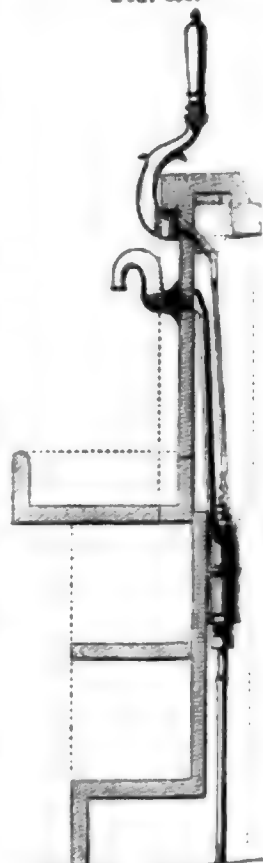
FIG. 304.



WATSON'S BEER-ENGINE, by Messrs. Gerardin & Watson, London.

driver. 6. *Screw bottle-stopper*, for reclosing a bottle after the cork has been drawn, specially useful for effervescing wines. It consists of a screw stem, with a bulb at the lower end, and a nut at the other, passing through an india-rubber collar. By turning the nut, the screw is drawn up, and the elastic collar is pressed by the bulb against the contraction in the gullet of the bottle, so as to resist any escape. The stem may be secured by a padlock, passed through a hole pierced in the stem. The stopper may be made hollow, with a tap and air-pipe, by the use of which portions of the liquid may be withdrawn without removing the stopper.

FIG. 305.



WATSON'S BEER-ENGINE (Section enlarged).

Messrs. Gerardin & Watson, London, exhibited *Watson's beer-engine*, which differs from others in having the lifters or levers fixed on the outside instead of the inside of the face,

leaving the top clear of slots, caps, and holes. The leverage, also, is greater, and the lever may be adapted to pint, $\frac{1}{4}$ -pint, or $\frac{1}{2}$ -pint motions (figs. 394 and 395).

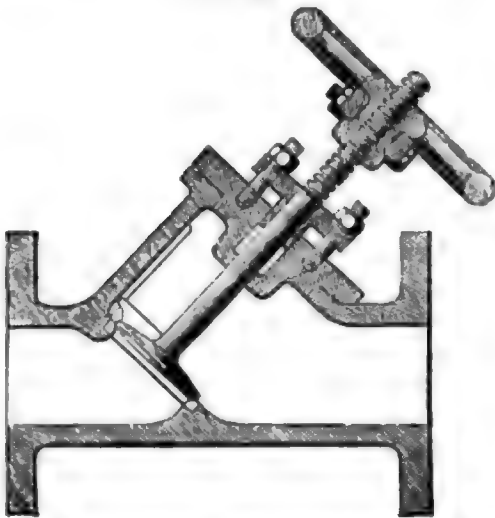
Mr. John Gallagher, Wolverhampton, exhibited a *self-acting bottling machine*, to fill six, eight, or ten bottles simultaneously, without causing frothing, and one, two, or three casks may be simultaneously drawn off and bottled. It is arranged with a trough and syphons, similar to the bottling machine of Messrs. Farrow & Jackson.

CHAPTER XI.

STOP-VALVES AND COCKS.

A great variety of well-executed brasswork was exhibited. Mr. W. P. Wilkins, Ipswich,

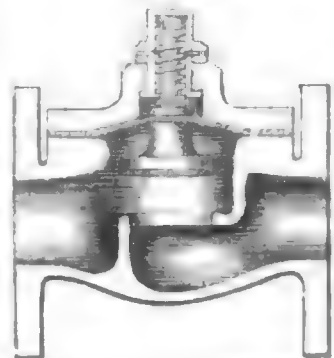
FIG. 396.



STRAIGHT-WAY STOP-VALVE, by Mr. W. P. Wilkins, Ipswich.

and Mr. John Beck, London, exhibited *straight-way stop-valves*, in which the valve is inclined in the direction of the motion of the water, so as to offer the least obstruction to the flow (fig. 396). Messrs. Thomas Lambert & Son, London, exhibited a *valve with india-rubber discs*, specially designed to close itself after a definite quantity of water has been discharged, so preventing waste of water (fig. 397).

FIG. 397.



GLOBULAR IRON STOP-VALVE, by Messrs. T. Lambert & Son, London.

Mr. S. Leoni, London, exhibited *taps* in a new material, "Adamas," which is a species of clay consisting of silicate of magnesia, reduced to powder, and formed by hydraulic pressure.

It is said to be free from liability to corrosion or oxidation, or destruction from heat or acids. It has been used for wine and beer taps, machine bearings, and gas-burner nibs. Mr. Henry Grissell has applied Adamas bearings under heavy pressures, equal, in one instance, to 2 cwt. per square inch, the shaft making 100 revolutions per minute, and he has stated that there is no abrasion nor heating. In applying them to a 4-foot fan, making 1,000 revolutions per minute, he states that they require oiling but once a day.

SECTION V.

PNEUMATIC MACHINERY.

CHAPTER I.

AIR-ENGINES.

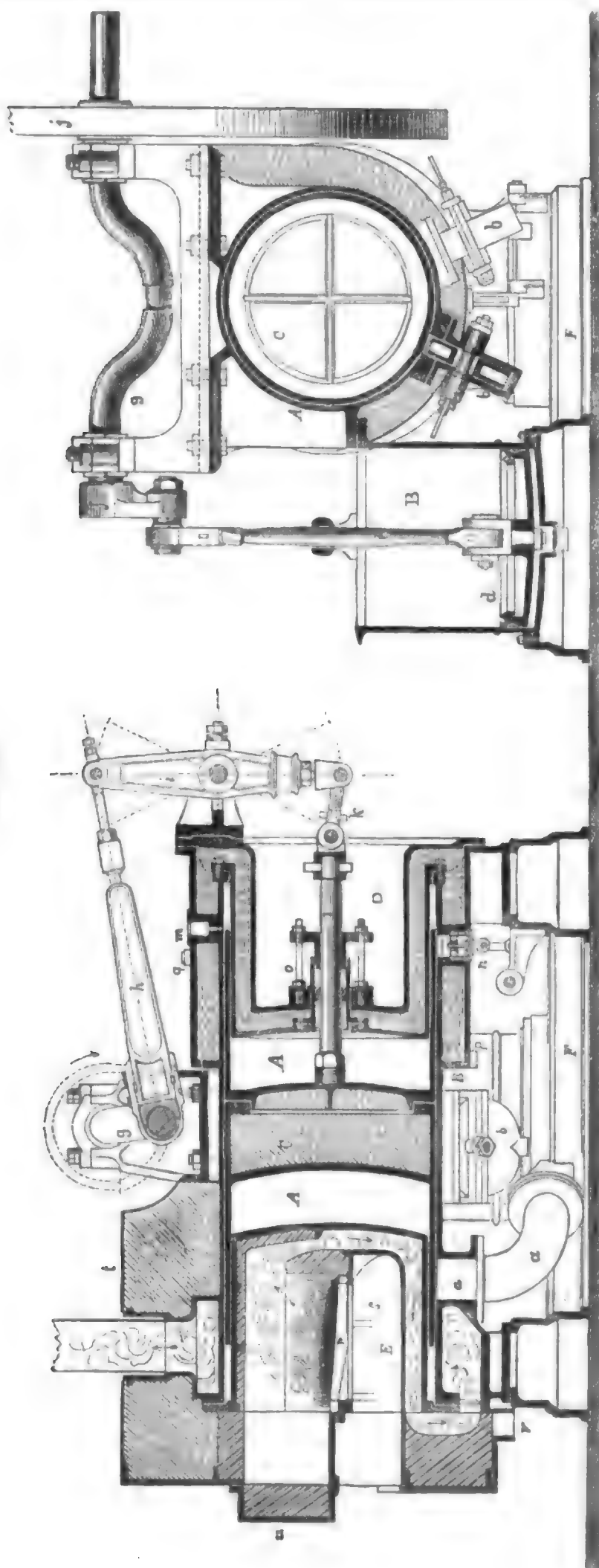
Mr. Ericsson, New York, exhibited a *caloric, or hot-air engine*. The Ericsson air-engine, or "caloric engine," as it has been called, long since abandoned for marine purposes, has been simplified by the suppression of the regenerator. In Germany, this engine is used in many small factories. A small engine, of 1-horse power, is reported to have consumed about 9 lb. of coal per horse-power per hour,—a result which is corroborative of those arrived at by M. Tresca.

Mr. E. B. Neill, London, exhibited an *Ericsson engine* of 2-horse power, applied to work a fire-engine. But the necessary power, of at least

five to six horses, for efficiently working a fire-engine, is much beyond what could be attained by an Ericsson engine without being excessively heavy. Mr. Neill's machine has a single horizontal cylinder, with two pistons working in it. These pistons, by their movements, draw into the space between them a volume of atmospheric air, and then compress it, forcing it into contact with the heated surfaces of the furnace. Heated and increased in pressure and in volume, the air exerts a proportional motive power.

Mr. C. H. Dennison, Rhode Island, U.S., exhibited *Wilcox's hot-air engine*, with two vertical cylinders, one of which is closed with a stuffing-box for the piston-rod in the usual way, and the other is open at the upper end. The close cylinder forces the air to be heated through

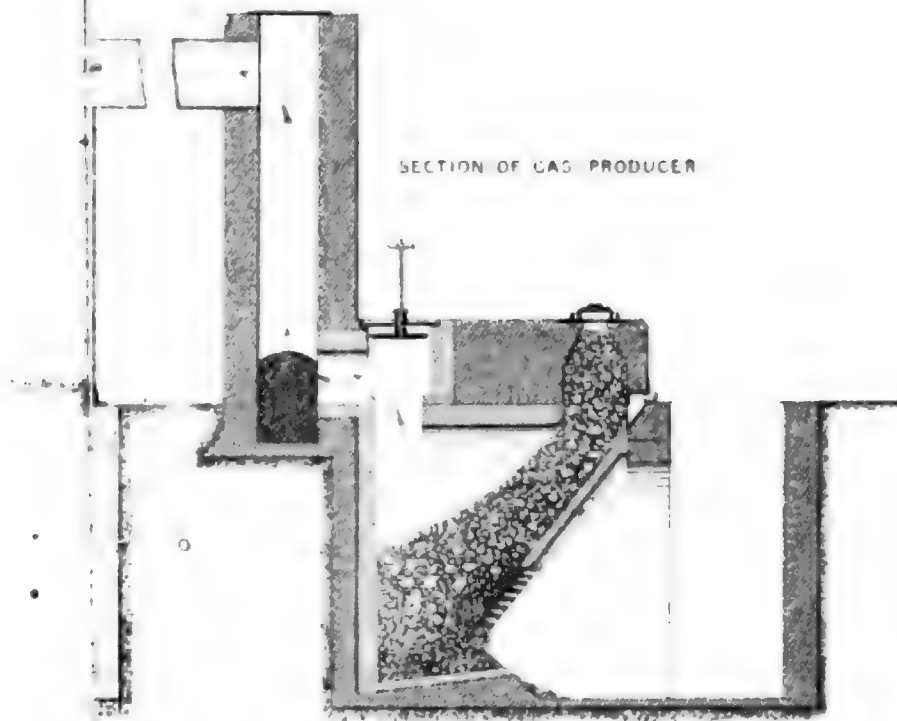
FIG. 398.



LAUBEREAU'S HOT-AIR ENGINE, by M. L. Schwartzkopff, Berlin. A, horizontal cylinder; B, vertical cylinder; C, tank; D, condenser; E, fire-chamber; F, sole-plate; G, hot-air tube; H, rollers to carry the tank; P, entrance and exit of cold water circulating through the water-chamber; d, working piston.

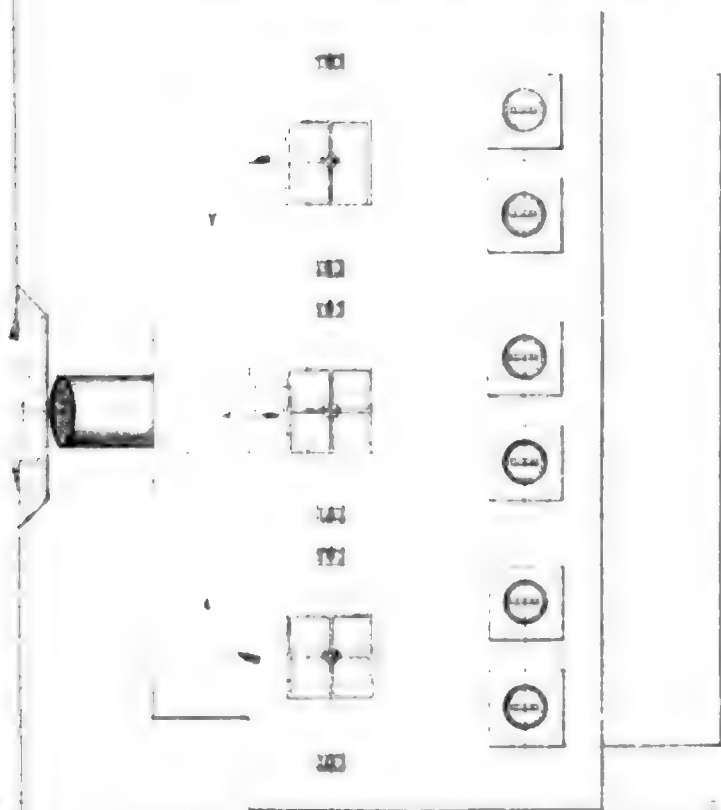
a series of corrugated sheet-iron plates, like Ericsson's regenerator, into the bottom of the second cylinder, where it is heated, and acts on the piston. It is then exhausted under the piston of the first cylinder, when it is further heated, and performs an additional item of work. The air is finally exhausted into the atmosphere through the regenerator, to which it imparts on its way out a portion of its surplus heat, to be delivered to the succeeding charge of external air, and escapes finally at a temperature scarcely above 212° Fahr. The steam is distributed by means of a cock. The cylinders and the pistons are formed with inverted conical bottoms, like those of ordinary quart bottles, for the sake of the strength to resist the action of the heat. This machine occupies considerable space in proportion to its power, and weighs 37 cwt. It is said by the inventor to be capable of exerting $1\frac{1}{2}$ horse power, with a consumption of $7\frac{1}{2}$ lb. of good anthracite coal per horse-power per hour. This engine, according to Mr. Wilcox, is only applicable for small powers.

M. Schwartzkopff, Berlin, exhibited *Laubereau's hot-air engine*, of from 1 to $1\frac{1}{2}$ horse power, which differs from others by the repeated use of the same quantity of air, transferring it backwards and forwards between the hot and cold ends of a receiver or cylinder alternately, instead of exhausting and renewing the supply of air at each stroke (see figs. 398). The working cylinder is in direct communication with the heating and cooling chambers, without valves or stoppages of any kind, so that there is an equal pressure in all parts of the machine. "A cylinder, with a diaphragm in the middle, containing a non-conductor of heat, is provided, the furnace being placed in one of the chambers thus formed, and the refrigerator, in the shape of a surface condenser, kept con-



SECTION OF GAS PRODUCER

PLAN OF THREE GAS PRODUCERS



stantly supplied with cold water in the other. This diaphragm is in connection by rods with the piston-rod of the working cylinder. Supposing it is now required to work the engine, the fire is lighted in the little furnace (it does not exceed a cubic foot in size), and when a sufficient temperature, 300° centigrade, has been obtained, the principal communication between the interior of the machine and the outer air is closed. The air in the heating chamber is expanded, and, rushing into the working cylinder, forces up the piston, and gives motion to the machine; but no sooner has it done so—in fact, by its very upward motion, the diaphragm is caused to move towards the furnace, when a partial vacuum is created in the cooling chamber; into this the hot air in the working cylinder rushes and is cooled, leaving in the working cylinder a partial vacuum, into which the pressure of the atmosphere instantly causes the piston to descend and fill. The working piston descending, forces the diaphragm towards the condenser; the cool air passes to the heating chamber, is reheated, and again acts on the working piston, this operation continuing as long as the fire is kept up. There is a small opening ($\frac{1}{8}$ inch diameter) from the exterior to the heating and cooling chambers, to admit of the entrance of sufficient air to compensate for waste."

CHAPTER II.

GAS-ENGINES.

M. Lenoir, Paris, exhibited a *gas-engine* in working condition. In general appearance it is like a horizontal steam-engine, with a piston reciprocating within a cylinder, propelled by the explosion of a mixture of gas and air at each end, alternately. The gas and air to be burnt are admitted to follow the piston during half the length of stroke; they are then shut into the cylinder by the valve, and exploded by an electric spark, and the products of combustion, by their expansive force, supply the motive force, which operates during the remaining half of the stroke. M. Tresca has estimated, from his experiments on M. Lenoir's engine, that it consumes about 90 cubic feet of gas per horse power per hour. The engine is started by simply opening a cock, and assisting the fly-wheel for two or three turns.

Mr. C. W. Siemens, London, exhibited a *gas-engine*, ingeniously constructed, which works on the same principle as M. Lenoir's. It is composed of four cylinders, of which the piston-rods are separately connected to the ends of the four arms of a cross, of which the centre works in a fixed bearing. The cylinders work consecutively, and their pistons rise and fall in succession, so that there are not any dead points in the system; and a continuous circular motion is taken from

the centre and transmitted by a connecting-rod to a crank on the shaft. The valves of the four cylinders are worked from a cam-plate on the shaft. A regenerator is provided for saving a great part of the heat which would otherwise be discharged with the waste gases; and there are theoretical grounds for expecting the engine to be economical.

Gas-engines consume, no doubt, a good deal of gas, but they might be conveniently adopted in certain situations in preference to a steam-engine; and there is this to be said for them, that they do not consume anything whilst standing. M. Tresca has suggested that the ordinary illuminating gas might be replaced by a liquid hydrocarbon, through which it would be sufficient to pass the air, and from which the air would absorb a proportion sufficient to constitute an inflammable mixture. Gas-engines appear to be specially applicable in cases where a limited supply of power is required—say from 1 to 3 horse power—at intervals, and where the use of steam is to be absolutely avoided.

Mr. Siemens exhibited also models of *C. W. & F. Siemens's regenerative gas furnaces*, arranged for the manufacture of flint glass (Plate XXXVIII). These furnaces are destined to occupy an important position in metallurgical and other operations, and they here deserve an extended notice, on account of their novelty and their great scientific and practical value.

Professor Faraday, in his lecture at the Royal Institution, on the 20th June, 1862, describes these furnaces in the following terms:—"The gaseous fuel is obtained by the mutual action of coal, air, and water, at a moderate red heat. A brick chamber, perhaps 6 feet by 12 feet, and about 10 feet high, has one of its end walls converted into a firegrate; that is, about half-way down it is a solid plate, and for the rest of the distance consists of strong horizontal plate bars where air enters, the whole being at an inclination such as that which the side of a heap of coals would naturally take. Coals are poured through openings above upon this combination of wall and grate, and being fired at the under surface, they burn at the place where the air enters; but as the layer of coal is from 2 to 3 feet thick, various operations go on in those parts of the fuel which cannot burn for want of air. Thus the upper and cooler part of the coal produces a large body of hydro-carbons; the cinders or coke which are not volatilized, approach, in descending, towards the grate; that part which is nearest the grate burns with the entering air into carbonic acid, and the heat evolved ignites the mass above it; the carbonic acid, passing slowly through the ignited carbon, becomes converted into carbonic oxide, and mingles in the upper part of the chamber (or gas-producer) with the former hydro-carbons. The water, which is purposely introduced at the bottom of the arrangement, is first vaporized by the heat, and then decomposed by the ignited

fuel, and rearranged as hydrogen and carbonic oxide, and only the ashes of the coal are removed as solid matter from the chamber at the bottom of the fire-bars.

"These mixed gases form the gaseous fuel. The nitrogen which entered with the air at the grate is mingled with them, constituting about a third of the whole volume. The gas rises up a large vertical tube for 12 or 15 feet, after which it proceeds horizontally for any required distance, and then descends to the heat-regenerator, through which it passes before it enters the furnaces. A regenerator is a chamber packed with fire-bricks, separated so as to allow of the free passage of air or gas between them. There are four placed under a furnace. The gas ascends through one of these chambers, whilst air ascends through the neighbouring chamber, and both are conducted through passage outlets at one end of the furnace, where, mingling, they burn, producing the heat due to their chemical action. Passing onwards to the other end of the furnace, they (that is, the combined gases) find precisely similar outlets, down which they pass, and, traversing the two remaining regenerators from above downwards, heat them intensely, especially the upper part, and so travel on in their cooled state to the shaft or chimney. Now the passages between the four regenerators and the gas and air are supplied with valves and deflecting-plates, which are like four-way cocks in their action; so that by the use of a lever these regenerators and airways, which were carrying off the expended fuel, can in a moment be used for conducting air and gas into the furnace; and those which just before had served to carry air and gas into the furnace, now take the burnt fuel away to the stack. It is to be observed, that the intensely heated flame which leaves the furnace for the stack always proceeds downwards through the regenerators, so that the upper part of them is most intensely ignited, keeping back, as it does, the intense heat; and so effectual are they in this action, that the gases which enter the stack to be cast into the air are not usually above 300° Fahr. of heat. On the other hand, the entering gas and air always pass upwards through the regenerators, so that they attain a temperature equal to a white heat before they meet in the furnace, and there add to the carried heat that is due to their mutual chemical action. It is considered, that when the furnace is in full order, the heat carried forward to be evolved by the chemical action of combustion is about $4,000^{\circ}$, whilst that carried back by the regenerator is about $3,000^{\circ}$, making an intensity of power which, unless moderated on purpose, would fuse furnace and all exposed to its action.

"Thus the regenerators are alternately heated and cooled by the outgoing and entering gas and air; and the time for alternation is from half an hour to an hour, as observation may

indicate. The motive power on the gas is of two kinds; a slight excess of pressure within is kept up from the gas-producer to the bottom of the regenerator, to prevent air entering and mingling with the fuel before it is burnt; but from the furnace, downwards through the regenerators, the advance of the heated medium is governed mainly by the draught in the tall stack or chimney.

"Great facility is afforded in the management of these furnaces. If, whilst glass is in the course of manufacture, an intense heat is required, an abundant supply of gas and air is given. When the glass is made, and the condition has to be reduced to working temperature, the quantity of fuel and air is reduced. If the combustion in the furnace is required to be gradual from end to end, the inlets of air and gas are placed more or less apart the one from the other. The gas is lighter than the air; and if a rapid evolution of heat is required, as in a short puddling furnace, the mouth of the gas inlet is placed below that of the air inlet. If the reverse is required, as in the long tube-welding furnace, the contrary arrangement is used. Sometimes, as in the enameller's furnace, which is a long muffle, it is requisite that the heat be greater at the door end of the muffle and furnace, because the goods being put in and taken out at the same end, those which enter last, and are withdrawn first, remain, of course, for a shorter time in the heat at that end; and though the fuel and air enter first at one end and then at the other alternately, still the necessary difference of temperature is preserved by the adjustment of the apertures at those ends.

"Not merely can the supply of gas and air to the furnace be governed by valves in the passages, but the very manufacture of the gas fuel itself can be diminished, or even stopped, by cutting off the supply of air to the grate of the gas-producer; and this is important, inasmuch as there is no gasometer to receive and preserve the æriform fuel, for it proceeds at once to the furnaces.

"Some of the furnaces have their contents open to the fuel and combustion, as in the puddling and metal-melting arrangements; others are enclosed, as in the muffle furnaces and flint-glass furnaces.

"The economy in the fuel is esteemed practically as one-half, even when the same kind of coal is used, either directly for the furnace or for the gas-producer; but as in the latter case the most worthless kind can be employed, such as slack, &c., which can be converted into a clean gaseous fuel at a distance from the place of the furnace, so, many advantages seem to present themselves in this part of the arrangement."

Professor Faraday concludes his lecture with the following conclusive figures:—

"Carbon, burnt perfectly into carbonic acid

in a gas-producer, would evolve about 4,000° of heat; but if burnt into carbonic oxide, it would only evolve 1,200°. The carbonic oxide, in its fuel form, carries on with it the 2,800° in chemical force, which it evolves when burning in the real furnace with a sufficient supply of air. The remaining 1,200° are employed in the gas-producer in distilling hydro-carbon, decomposing water, &c. The whole mixed gaseous fuel can evolve about 4,000° in the furnace, to which the regenerator can return about 3,000° more."

The advantages of the regenerative gas-furnace are thus summarised by Mr. Siemens:—1st. Saving of fuel, amounting to from 40 to 50 per cent. in the quantity; besides which, the most inferior qualities of fuel, such as slack, coke-dust, lignite, and peat, may be employed, producing a money saving, in many instances, amounting to 75 per cent. 2nd. Unlimited command of heat without intense chimney-draught, owing to the principle of accumulation involved. 3rd. Great purity and gentleness of flame, which greatly diminishes the oxidation, or deterioration, of the material heated in the furnace, and improves the quality of the produce. 4th. Increased durability of furnace, owing to the absence of ashes, and a perfect uniformity of heat throughout the furnace. 5th. Saving of space within the works, and great cleanliness of operation, the fuel being converted into gas outside the works. 6th. Complete command of the intensity of the heat, and of the chemical nature of the flame, which may be arrested, or changed from a reducing to an oxidizing flame, or the reverse, at any one moment, tending to facilitate and improve all metallurgical operations. 7th. Complete absence of smoke from the stack, which renders this furnace beneficial to the public in large towns.

CHAPTER III.

AIR-PUMPS.

Air-pumps are specially represented by the vacuum-engines employed for the evaporation of syrups in the manufacture of sugar. Vacuum-engines have already been noticed, with other sugar-refining apparatus (see page 263, *ante*).

Messrs. Gargan & Co., Paris, exhibited drawings of a *gas-exhausting engine*, designed for drawing off the gas produced in the retorts employed in its manufacture, at such a rate as to maintain the gas at a pressure not exceeding that of the atmosphere. Leakage of gas is thus prevented, which otherwise takes place, not only through holes or fissures, but even through the material of the retorts themselves. A saving of 16 per cent. in gas is reported to have been made by the application of the exhauster. The

exhauster also forces the gas through the purifiers. The engine consists of one steam-cylinder, and works three parallel double-acting gas-cylinders, by means of which, with the aid of a gas-holder, a steady current is obtained. This engine has successfully superseded the fan previously employed for exhausting the gas, and with considerable economy of power.

M. Silbermann, Paris, exhibited an *air-pump*, for use as a philosophical instrument, in which a multiple-way cock is applied, for the purpose of opening a communication between the pump and any one of these vessels, from which air or gas may be withdrawn and forced into one of the others.

The blast-engines exhibited by the Lilleshall Company, and by M. L. Pérard, have already been noticed with steam-engines (see pages 308 and 317, *ante*).

CHAPTER IV.

FANS.

Mr. George Lloyd, London, exhibited his *noiseless disc fan*, which was also exhibited in 1851, and in 1855. The blades are curved backwards, and are tapered in width, being narrowed towards the circumference, and enclosed and fixed air-tight within two conical discs, which revolve with them. The complete conduction of the air between the discs, without loss by leakage at the sides of the blades, not only improves the efficiency of the fan as compared with the older and common sort, but also renders it noiseless. According to the experiments made by the Jury in 1851, by means of Morin's dynamometer, on a 30-inch Lloyd's fan, the highest efficiency, or proportion of work yielded by it, was 34 per cent. of the power transmitted to it.

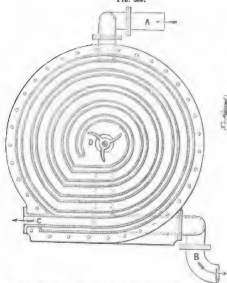
Mr. John R. Davison, London, exhibited a *hot-air fan*, otherwise called the *thermantérion*—pure Greek!—which, being translated, means a box of heat. It is a cleverly designed and efficient machine for propelling and at the same time heating a current of air. The fan is placed in the centre of a large flat case of a spiral form, into the coils of which hot water or steam is admitted. The air is propelled between the coils, and absorbs heat from the heated surfaces on its passage towards the circumference. A machine to propel 2,000 cubic feet of heated air per minute is said to be capable of being worked by 1½-horse power. The machine is suitable for heating buildings, and for drying purposes (fig. 399).

Mr. James Howorth, Farnworth, Bolton, exhibited his *revolving Archimedian screw ventilators*, or windmills, for ventilating public or private buildings. They are 30 inches in diameter, and are made to be turned by steam or

other power. They are said to be extensively employed for expelling accumulations of hot air,

exhibited *Platt & Schiele's silent fan*. It has but one central entrance for air, on one side, and the

FIG. 399.



HOT-AIR FAN, OF THREMANTERSON, by Mr. John H. DAVISON, London.
A, inlet for screw; B, outlet for condensed steam; C, outlet for hot air; D, the fan.

sulphurous gases, dirt, waste-flyings, &c., incidental to factories, stables, &c. The principal

FIG. 400.

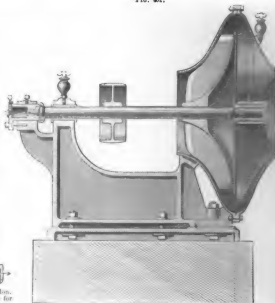


REVOLVING ARCHIMEDEAN SCREW, by Mr. Howorth, Farnworth, Bolton.

The North Moor Foundry Company, Oldham,

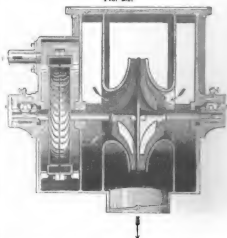
features are the hood, the screw, and the means of lubrication by internal arrangements. The hood is formed with lateral vanes for the escape of the hot air, and to prevent rain or wind beating in. A distinct series of curved vanes are fixed upon the top of the hood, to be acted upon and revolve by the wind. The screw is fixed on the spindle of the hood, and revolves with it, producing a continuous exhausting current upwards. The screw ventilator, it is stated, will work from four to six years, in good condition, freely and noiselessly (fig. 400).

FIG. 401.



PLATT & SCHIELE'S SILENT FAN, by the North Moor Foundry Company, Oldham.

FIG. 402.



SCHIELE & WILLIAMS'S BLAST-ENGINE, by the North Moor Foundry Company, Oldham.

air is expelled from the case at the opposite side, in the direction of the axis of the fan. These fans are said to be capable of exhausting

20,000 cubic feet of air per lb. of coal consumed in driving them, producing a vacuum equal to $1\frac{1}{2}$ inches of water. For the purpose of increasing the force of the blast, two or more fans are joined together, the first discharging the air at a pressure of $\frac{3}{4}$ lb. per square inch into the second, from which it receives an additional impetus, represented by an extra pressure of $\frac{3}{4}$ lb. per square inch, before being finally discharged, or delivered to a third fan for further compression (fig. 401).

The same firm exhibited a "*blast-engine*," or blowing fan, patented by Messrs. Schiele & Williams, consisting of a fan having its wings curved and tapered, expelling the air at the circumference, mounted on the same shaft with a steam-turbine which drives it. This fan is particularly applicable to the ventilation of steam and sailing vessels (fig. 402).

M. Lemielle, Valenciennes, exhibited a *ventilating fan* for coal-mines, which by its action produces air-chambers of various capacity, and acts rather like a piston-machine. It is said to give good results in ventilating mines, and it is employed also as an air-blast in large works.

The Vienna Imperial and Royal Commission for the ventilation of military hospitals, Vienna, exhibited *Dr. Heger's screw ventilator*, consisting of a screw or wheel, with inclined blades, enclosed in a tube. The rotary motion of the screw sets the air in motion through the tube.

It is stated that this ventilator has attained an efficiency equal to 55 per cent. of the power applied to it.

CHAPTER V.

ELECTRO-MAGNETIC ENGINE.

Mr. H. C. Hurry, Worcester, exhibited an *electro-magnetic engine*, deriving its motive power from the united force of attraction and repulsion of electro-magnets. A revolving disc, 7 feet in diameter, carries four tiers of magnets, which are respectively opposite, and revolve within, four concentric tiers of magnets fixed into an external casing as closely as is practicable without actual contact. There are 220 magnets in each tier in the revolving disc, and only 200 in each of the exterior tiers. The polarity of the revolving magnets is changed at the instant of passing each of the fixed magnets, so that by an alternate exercise of attraction and repulsion, in approaching and receding, a motive power is exerted, causing the disc to revolve. The machine was estimated by Mr. Hurry to be capable of exerting 20 actual horse-power; but it was never put to work. The estimated power is probably too high.

SECTION VI.

UNCLASSED MACHINES.

CHAPTER I.

STEAM CRANES AND WINCHES.

Messrs. A. Chaplin & Co., Glasgow, exhibited two *5-ton portable steam-cranes*, which were employed in the Western Annex in loading, unloading, and distributing the goods for exhibition; and this they did in a very satisfactory manner. The crane is erected upon a plate-iron carriage, on four wheels to run on rails or on the ground. The central pillar is bolted to a large sole-plate with a circular race of considerable diameter, to carry the friction-rollers at the foot of the jib, and receive the thrust. The engine and boiler can be swung completely round on the pillar, and they counterbalance the load in all positions. There is a commodious platform at the back of the boiler for the driver, whence he can work the crane. The water-tank is on one side of the boiler, and the coal-box is below it. The engine has two steam-cylinders 6 inches in diameter, with 10 inches of stroke, with the link-motion for starting and reversing; and the gearing is made with two motions, for hoisting and lowering, and for turning round,

either of which can be put into gear by a hand-clutch, whilst a brake is worked by the foot to regulate the descent of the loads. The turning motion is effected by means of a worm working into a spur-wheel fixed on the pillar. The boiler is vertical, with upright flue-tubes, which are not parallel-sided as usual, but tapered upwards from the lower end to just below the water-line, whereby they are enlarged to their full diameter and carried straight up through the steam-space. The object of this formation of the tubes is to aid in detaining the heat, communicating it to the water, whilst the upper and under portions which pass through the steam-room superheat the steam to a greater or less extent, and are uninjured by the heat escaping through them. With steam of 50 lb. pressure per square inch, the cranes have lifted $7\frac{1}{2}$ tons, making 100 revolutions of the engine per minute. The purchase is about 40 to 1. The jibs may be raised or lowered by means of a worm and wheel on the top of the column (fig. 403).

Messrs. Chaplin & Co. exhibited also a *ship's engine*, with *apparatus for winding, cooking, and*

FIG. 473.

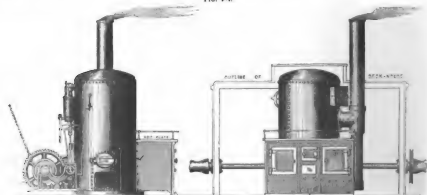


5-TON PORTABLE STEAM-CRANE, by Messrs. Chaplin & Co., Glasgow. Employed in the Western Annex, for loading and unloading the Goods.

distilling, in combination. It is for use on board ships of every class, and more especially in the larger class of sailing and passenger ships. It is so arranged that one fire serves

both for the steam-boiler and for cooking operations in the galley. The total consumption of fuel is said not to exceed that of an ordinary cooking galley, whilst the steam-

FIG. 494.



SHIP'S ENGINE, with Apparatus for Winding, Cooking, and Distilling, by Messrs. Chaplin & Co.

engine and hoisting-winch are always ready for aiding the crew in performing the heavy work of the ship, as heaving anchors, discharging cargo, working the ship's pumps. The engine

is fitted with the link-motion for reversing; the main hoisting-barrel is applied to the heavier work of taking in or discharging cargo; whilst the barrel-shaft is prolonged through

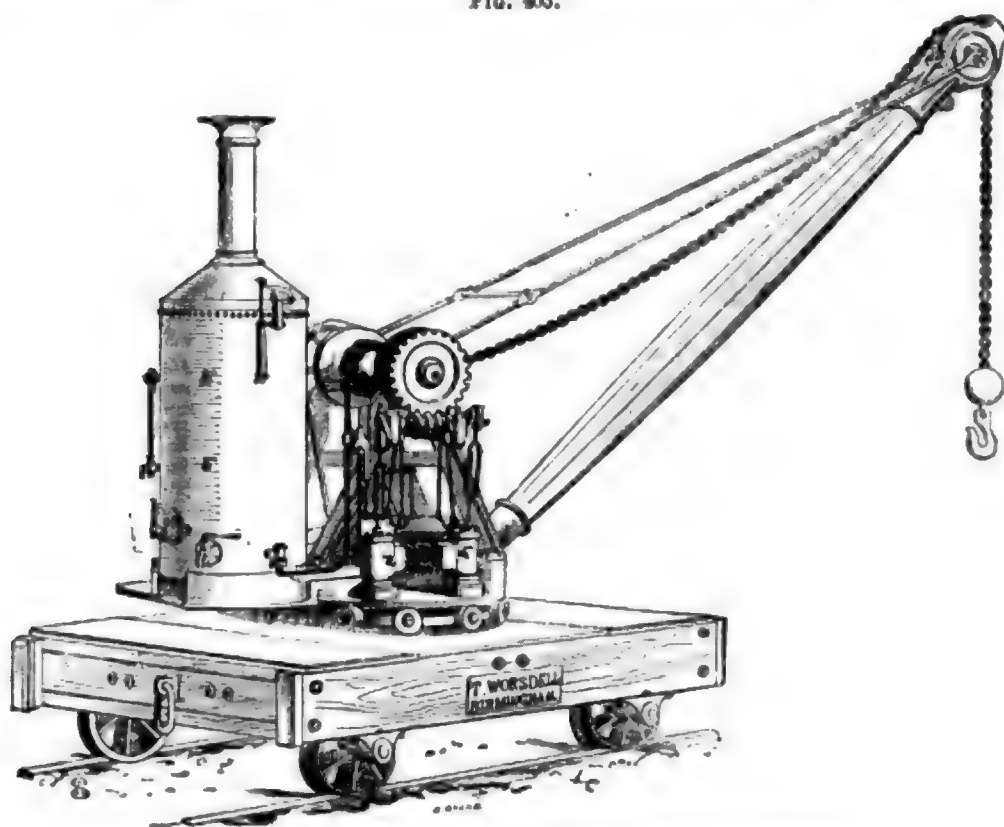
the sides of the deck-house, with a winch on each end to give a purchase for setting sails, &c. The ship's pumps and the windlass are driven by means of endless pitch-chains. The ovens and hot plates are placed at the back of the boiler, to which the hot gases are conducted from the boiler furnace through an opening in the side of the boiler regulated by a valve. Boiling may be conducted in the tanks by means of steam in pipes from the boiler. A supplementary fire may be lighted up in the range when the boiler is under repair (fig. 404). The distilling apparatus for providing fresh water has already been noticed. (See *ante*, page 274.)

Messrs. Lumley & Watson, London, exhibited a 3-ton ship's steam-crane, applicable also for wharfs. This crane is compactly arranged, apart from the boiler, upon a fixed central pillar let through the deck, into a bearing below. There are two upright cylinders, $5\frac{1}{2}$ inches in diameter, 10 inches stroke, bolted to the frame-sides at the lower part, and connected to the crank-shaft overhead. The steam-pipe is carried below the deck, into the interior of the pillar, and passed up through the top, and thence to the cylinders. It is exhausted into an annular chamber surrounding

the post, from which it passes off through the post, and away by a pipe under the deck and through the side of the ship. By means of a circular rack fixed at the base, the crane may be turned completely round by steam. When goods are lifted to the proper height, they are held there by a brake, and the gearing shifted, when the crane may be turned round by steam, making a complete revolution if required. The goods are then lowered by the brake. Steam of 30 lb. pressure per square inch is sufficient to work the crane. This is a compact and useful crane, and cleanly, as the steam-pipes are kept out of the way.

Mr. T. Worsdell, Birmingham, exhibited a 30-cwt. portable steam-crane, working on a turntable with live rollers, with the boiler attached as a counterweight; the whole being placed on a low railway-truck, with four cast-iron wheels, and with prolonged axles to receive plain wheels for running on common roads when required. The foundation-plate is a strong ribbed casting, which extends the whole length and breadth of the oak framing of the carriage to which it is bolted. The base frame-plate of the crane is a deep ribbed hollow casting, serving as a reservoir for feed-water; and between it and the

FIG. 405.



30-CWT. PORTABLE STEAM-CRANE, by Mr. T. Worsdell, Birmingham.

foundation-plate the live rollers are interposed, so that the crane may be turned by hand when carrying the load. There are two cylinders, $3\frac{1}{2}$ inches in diameter, with 6 inches stroke, which turn a worm-shaft, gearing with a wheel on the end of the shaft carrying the barrel. The worm, with the four excentrics employed to work the link-motion for reversing, is formed out of the solid iron. The barrel is 6 inches in diameter;

it is loose on the shaft, and is tightened by means of friction-cones put in and out of gear by a screw, so that adhesion is had for lifting weights, and friction for lowering them when required, without reversing by steam. This method of lowering, by using the friction-cones as a brake, is very efficient in practice, and can be done, if required, without stopping the engines. The jib is usually made of wood, and has about 11 feet radius.

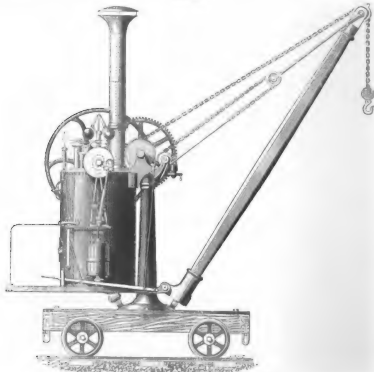
The speed at which the weight may be raised is estimated at the rate of 30 feet per minute. The boiler is cylindrical and upright, 2 feet 3 inches in diameter, and 4 feet high; it contains 40 flue-tubes $1\frac{1}{2}$ inch in diameter and 2 feet 9 inches long. The exhaust-pipe passes upwards through the centre. The firebox is concentric (fig. 405).

Mr. Worsdell also exhibited a series of *hydraulic jacks*, one of which weighs 144lb., and is capable of lifting 40 tons of load 10 inches high; a *traversing screw jack*, with a solid brass body, to lift 15 tons; a *hydraulic wire-tester*, to prove to 8 tons, weighing, with the case, 106lb.;

and a *hydraulic girder-tester*, to prove to 100 tons, weighing 3 cwt. 98lb., on four wheels.

Messrs. Appleby Brothers, London, exhibited a *portable steam-crane*, having the engine, boiler, and gearing framed together, and hung upon and revolving round a central pillar, to balance the load. The cylinder is upright, and fixed upon one side of the boiler, and working a crank-shaft overhead. The foot of the jib runs upon a small circular race—scarcely large enough for stiffness,—at the base of the column. There is a governor to regulate the speed. Query, is it required! The whole apparatus is fixed upon a four-wheeled truck (fig. 406).

FIG. 406.



PORTABLE STEAM-CRANE, by Messrs. Appleby Brothers, London.

Messrs. Ransomes & Sims, Ipswich, exhibited a *5-horse power portable steam-crab*, fitted with Biddell & Balk's boiler, before noticed (*ante*, p. 327). The crab, engine, and boiler are all carried on four wheels. The crab is capable of raising about 25 cwt., at a rate of from 70 to 80 feet per minute, and consists of a horizontal drum, beneath the boiler. The rope, which generally passes through a snatch-block, and over the swivel pulley on the fore carriage, is wound up

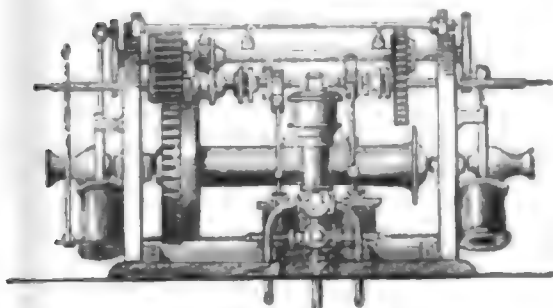
on the winding-drum, which is furnished with a ratchet-wheel to retain it in its position, and also with a lever and rollers to enable the driver to coil the rope properly. The brake, worked by the foot, assists in lowering and stopping suddenly, and is released by means of a counterweight when the foot is removed. The engine is made to reverse, to facilitate starting, and for the purpose of unwinding the chain or rope as the drum, so as to aid in the descent of the end

of the chain or rope. The crab can be worked by one man standing in one place (figs. 407).

Messrs. James Taylor & Co., Birkenhead, exhibited a *steam-winch*, with two steam-cylinders working diagonally, one at each

through snatch-blocks. At a given signal, by means of a white flag, the engine was started,

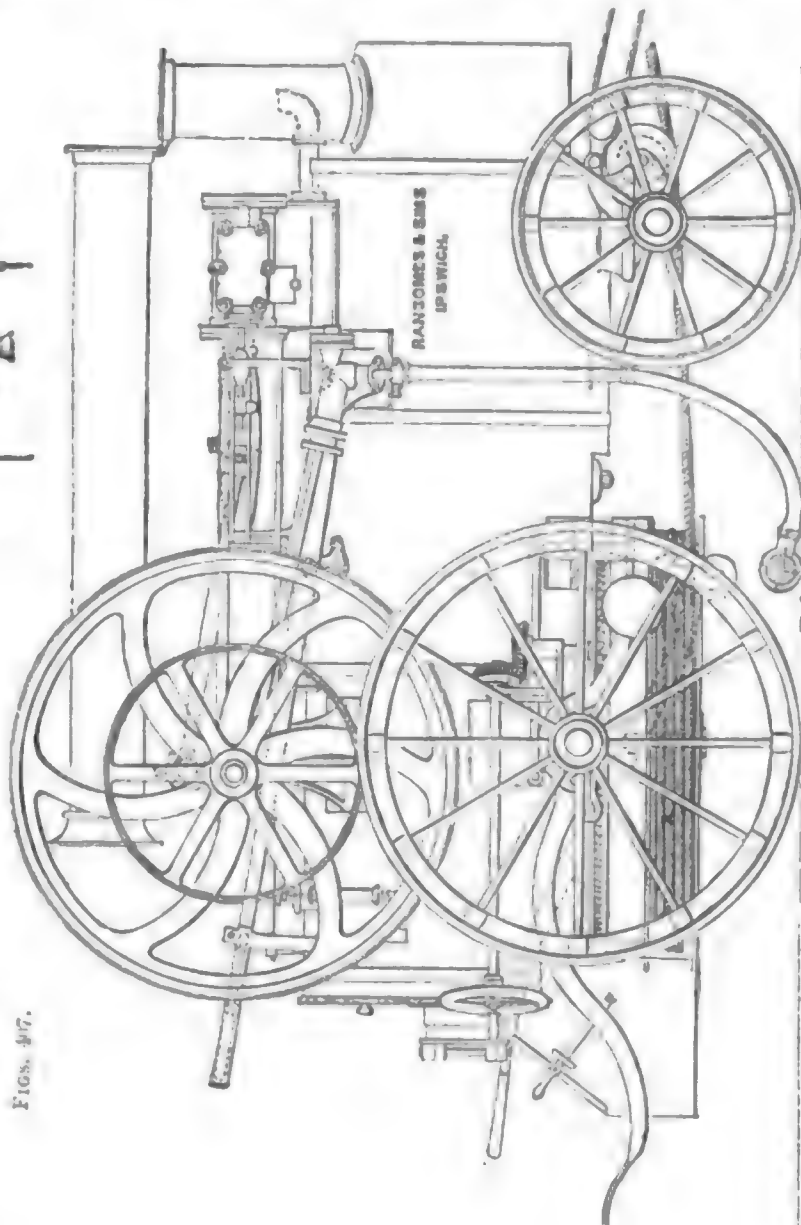
FIG. 408.



STEAM-WINCH, by Messrs. James Taylor & Co., Birkenhead.

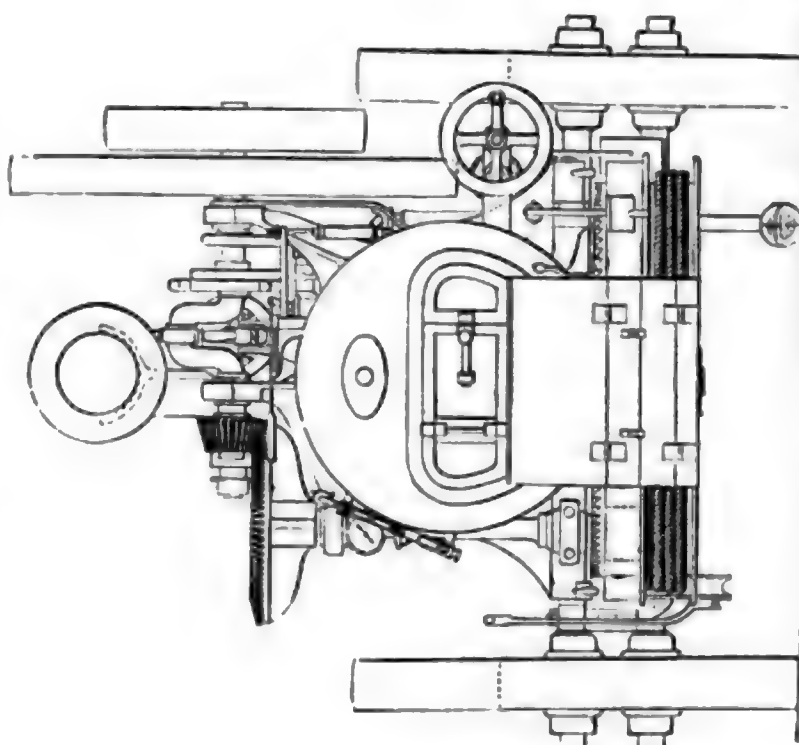
end of the winch, to a crank-shaft overhead, with double speeds. A windlass is fixed on one end of the barrel-shaft, and a drum on the other end for a quick purchase. A friction-wheel is applied, braked by the foot. The link-motion is applied for starting, stopping, and reversing. The steam-winch is adapted for use on shipboard, and is said to be capable of doing from 80 to 100 tons per hour; it is occasionally fitted with deck-pumps (fig. 408).

Mr. P. Ashton, London, exhibited one of the *steam-hoists* designed by him, with the 7-horse power portable engine by which it was driven, for the purpose of hoisting the heavy pieces employed in the construction of the Exhibition building. The hoist consists of two grooved cast-iron barrels, which are made to revolve by means of a system of toothed gearing, driven by the portable engine. A rope is placed several times over the barrels, and on the fall being manned and the barrels set in motion, the coils of the rope are gathered up, and great hoisting power is obtained. The engine is fitted with the link-motion for starting, stopping, or reversing at a second's notice. Two such steam-hoists were sufficient for the service of the building. Each hoist having been secured to four piles driven into the ground, and connected to the engine by a driving-belt, ropes were laid from the hoist to all parts of the building,



FIGS. 407.

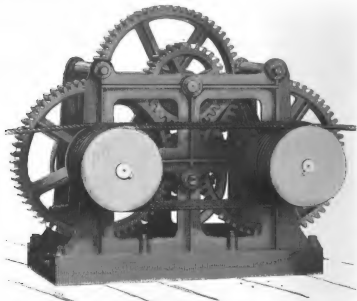
6-HORSE-POWER PORTABLE STEAM-CRAB, by Messrs. Ransomes & Sims, Ipswich.



and the loads, as girders, columns, and beams, were hoisted to the requisite elevation when the stop-signal was given by means of a red flag, and promptly obeyed. The average speed of lifting was 25 feet per minute; for instance, girders weighing $1\frac{1}{2}$ tons each were hoisted 50 feet high in two minutes. The main ribs of the nave were hoisted in two pieces, weighing

3 tons each, and hoisted in six minutes. Mr. Ashton's steam-hoists were distinguished for their safety, steadiness, and power; there are no undue strains or jerking of the tackle, and the adhesion of the rope is so considerable, that loads of three tons have been hoisted whilst the fall has been held by a finger and thumb (fig. 409).

Fig. 409.



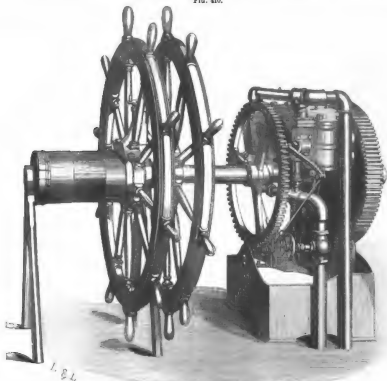
STEAM-HOIST, by Mr. Peter Ashton, London. Employed in the Construction of the Exhibition Buildings.

Mr. F. E. Sickles, New York, exhibited a *steam-steering apparatus*, which enables one person to control the course or direction of a ship with ease. The machine exhibited was taken off the steamer *Augusta*, while she was lying at the port of New York, in order to be sent for exhibition (fig. 410). The machine consists principally of two steam-cylinders working, at right angles, upon a pinion-shaft, gearing into a large spur-wheel fastened on the spindle of the steering windlass, by the medium of a friction-plate lined with wood, of adjustable tension. The slide-valves of the engine are worked by hand, by means of one of the two hand-wheels,—the rear one,—and a spur-wheel and pinion, the eccentrics being fixed on the spindle of the pinion. Thus the process of steering is perfectly under control, and is accomplished with ease. The second of the two wheels is available for hand-steering, should it be required to be resorted to; and by means of a screw-clutch, the hand-steering apparatus may be disconnected from the steam-gear. The

captain of the steamer *Augusta* writes thus of the Steam Steering-Machine on the 10th April, 1860:—"The value of this improvement was clearly shown during a heavy gale: it required but one man to steer, and this he did without the application of more power by him than could be exerted by one hand, it being only so much as was necessary to work the balance-valves. The large rudder, with ample steam-power to operate it, gave to the pilot far greater control of the movements of the vessel, in every emergency of our situation, than could have been obtained without the use of this steering apparatus; and to this superior control of the vessel during the gale I attribute the fact that we saved the boat, and were able to reach Norfolk. When the rudder was struck by a heavy sea, the friction-wheel enabled the rudder to yield to the pressure without breakage of the steering-chains, or any possible injury to the pilot."

The Patent Frictional Gearing Company, Glasgow, exhibited a 2-ton *steam-winch*, fitted

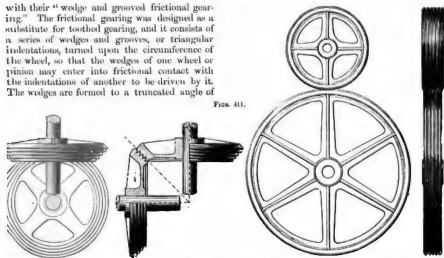
FIG. 410.



STEAM STEERING-APPARATUS, by Mr. F. E. Sickles, New York.

with their "wedge and grooved frictional gearing." The frictional gearing was designed as a substitute for toothed gearing, and it consists of a series of wedges and grooves, or triangular indentations, turned upon the circumference of the wheel, so that the wedges of one wheel or pinion may enter into frictional contact with the indentations of another to be driven by it. The wedges are formed to a truncated angle of

FIGS. 411.



FRICTIONAL GEARING, by the Patent Frictional Gearing Company, Glasgow.

35°, measured in section, and the bite or adhesion is generally about one and a half times the pressure or force exerted to hold the wheels in contact. (For various illustrations, see figs. 411.)

In the application of the frictional gearing to the winch, two steam-cylinders are applied, 6 inches in diameter, with 10 inches stroke, turning a 5-inch pinion with six wedges on its circumference, which drives a 3-foot wheel with five ribs, and a 6-inch barrel on the same axle. The clutching action is very simply performed, by drawing the pinion out of or into contact with the wheel, by means of a lever with eccentric bearings. The frictional gearing was also applied to work Mr. Davison's hot-air fan-blast, for which purpose it appears to be very well adapted.

The smooth action of the frictional gearing, free from concussion and back-lash, are obvious advantages. It would be desirable to test the proportion of power consumed in overcoming the rubbing friction that must necessarily take place between the wedges, together with the friction due to the lateral pressure on the bearings, which probably is greater than what arises in well-made toothed gear.

CHAPTER II.

ORDINARY CRANES AND OTHER HOISTING TACKLE.

Messrs. Bowser & Cameron, Glasgow, exhibited *Henderson's moveable-derrick cranes*, which are well known. They were employed in the construction of the Exhibition building, and also in that of 1851, and in unloading and loading the goods brought for exhibition. The derrick is adjustable to any angle, so that the crane commands three-fourths of the entire area within its range round the centre. The cranes performed the duty with ease and expedition.

Messrs. Forrest & Barr, Glasgow, exhibited a model of a *safety derrick crane*, in which the gearing is arranged by means of a simple clutch-movement, in such a way that the barrel for raising or lowering the jib or derrick cannot under any circumstances be left free to rotate of itself, as the movement by which it is disconnected from the

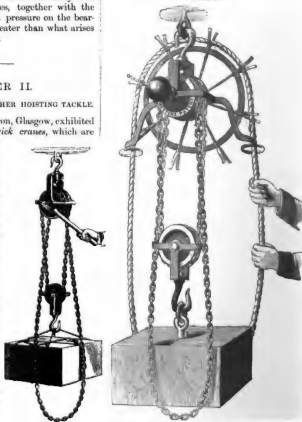
main hoisting-barrel at the same time puts it in gear with a fixed clutch or with separate gearing. The gearing is so arranged that the radius of the crane can be altered with little or no variation in the elevation of the load.

Mr. D. Hart, London, exhibited a *weighing crane*, by means of which the load may be weighed whilst it is suspended by the crane.

Hind's weighing crab, exhibited by Mr. Kitchin, has already been noticed, in connection with his engine-weighing machine (see *ante*, page 41).

Sir W. G. Armstrong & Co., Newcastle-on-Tyne, exhibited their well-known *hydraulic cranes and capstans*. The steam-power is in the first place employed to work a set of three-throw pumps to supply the accumulator, or reservoir of water under pressure, from which the water is distributed according to the want of water-pressure engines, through which the power is transmitted to the cranes, by multi-

FIGS. 412.



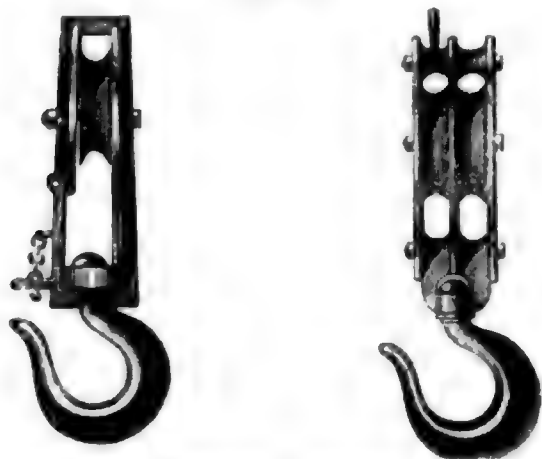
DIFFERENTIAL PULLEY-BLOCKS, by Mr. T. A. Weston, Birmingham.

plying tackle, so as to cause a rapid elevation of the load at the end of the chain. The rotation of the crane is also effected by the pressure of the water. The reservoir furnishes an advantageous means of maintaining the continuous work of the machine with the intermittent work of the crane. The capstan is worked by a three-throw pump, on the shaft of which a bevil pinion works a wheel fixed at the base of the capstan.* (See also page 393.)

Mr. T. A. Weston, Birmingham, exhibited his *differential pulley-blocks*, or hoisting-tackle, on the principle of the differential cylinder or Chinese windlass. An endless chain is passed over a double-sheave block, of which the two sheaves are cast in one piece, and it hangs down in two loops, in one of which a single block is hung, with a hook for carrying the load to be hoisted. The two sheaves of the upper block are of different diameters, and hence the purchase is obtained,—a purchase of about 22 to 1; that is to say, when 22 links of the chain pass over the larger sheave, the load is lifted the length of one link. But the purchase may of course be varied. The chain-links secure a hold on the sheaves by teeth fixed in the grooves, and the slight tendency to run down is prevented by the friction of the tackle. Lifting or lowering is effected by pulling at one side or the other of the loose chain. This very convenient and efficient hoisting-tackle has been only introduced extensively within the last two years (figs. 412, page 420.)

Messrs. Lumley & Watson exhibited *crabs* and *pulley-blocks*, the latter of which

FIGS. 413.



PULLEY-BLOCKS, by Messrs. Lumley & Watson, London.

were employed in the erection of the domes of the Exhibition building (figs. 413).

Lifting-jacks.—A great variety of jacks were exhibited, worked by screws, or gearing, or by hydraulic power, for which a small pump is worked to raise the plunger. The pump is in

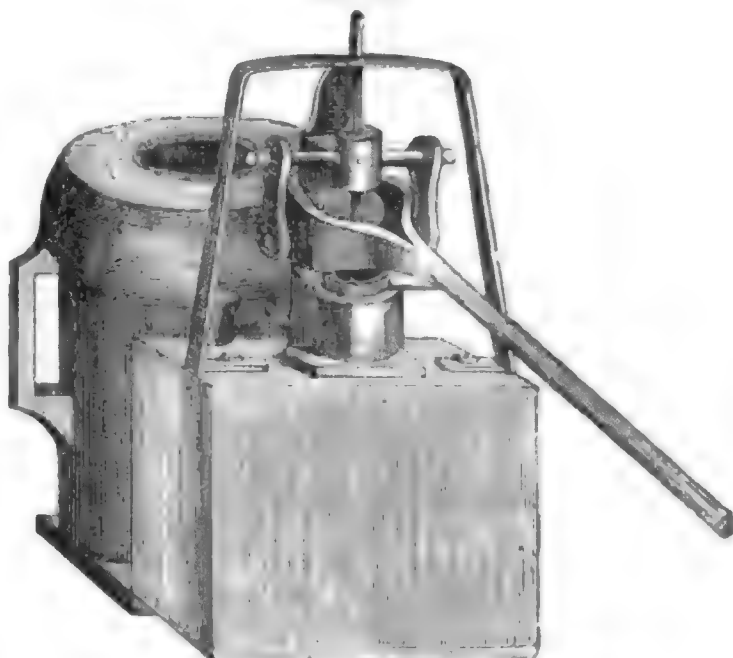
* For a full account of the water-pressure machinery constructed by Sir W. G. Armstrong & Co., see the "Proceedings of the Institution of Mechanical Engineers" for 1858.

some instances placed outside, but more commonly inside with the plunger, constituting an apparatus simple and easily worked. The friction by hydraulic action is, no doubt, less than with gearing, but the bursting action of frost is to be feared, and it may be questioned whether the valves can maintain the pressure without diminution for a length of time. The hydraulic jack nevertheless appears to be extending in use. They lift more rapidly than screw-jacks; lowering can be done under complete control, regulated to any speed, and stopped at any point.

Messrs. D. Adamson & Co., Hyde, exhibited *hydraulic lifting-jacks*, which are made of various sizes, to lift from four tons to fifty tons. An hydraulic pump is placed inside at the lower end of the lifting-ram. The upper part of the ram and the head of the jack form a self-contained cistern for oil or water, no more fluid being used than is required to lift the ram the whole of the stroke. A separate claw or foot-lift is supplied, and can be used at any time by slipping it upon the jack-head: it slides up the pillar. Thus, for general purposes, the jack may be kept free from inconvenient projections. The cylinder is one solid forging; so is the ram, with the addition of a separate steeled head.

Messrs. Huxhams & Brown, Exeter, exhibited an *hydraulic lift*, for raising and pushing heavy weights. The exhibitors state that ships of from 200 to 400 tons can be gradually raised by it.

FIG. 414.



HYDRAULIC LIFT, by Messrs. Huxhams & Brown, Exeter.

It is useful for a variety of heavy work, where a severe strain is to be slowly overcome (fig. 414).

Messrs. Tangye, Brothers, & Price, Birmingham, exhibited an *hydraulic lifting-jack*, which is regulated by a screw. The foot and cylinder are forged in one piece (fig. 415).

Messrs. George England & Co., London, exhibited their well-known *traversing screw-jacks*, by

means of which a load may not only be lifted, but also traversed, by means of a horizontal screw in the base, turned by means of a ratchet-

FIG. 415.



HYDRAULIC LIFTING-JACK, by Messrs. Tangye, Brothers, & Price, Birmingham.

handle. They have been extensively supplied for locomotive engines, and are most useful in replacing an engine on the rails when thrown off by accident.

Foreign Cranes.—Messrs. Parent, Schaken, Cailliet, & Co., Paris (the celebrated continental contractors), exhibited a crane with the Galle chain, on Neustadt's system. The chain is made like a watch-chain, without welds, in pieces pinned together, which gear with a pinion or indented wheel, by means of which it is wound up or let out without the intervention of a winding-barrel. The jib or derrick is constructed of two curved wrought-iron plates, with flanges, by which they are bolted or riveted together, so as to form a stiff hollow beam. Many cranes on this system are at work in France.

M. Fauconnier, Paris, exhibited several cranes fitted with the Galle chain, and wrought-iron box-girder jib. A large crane capable of lifting 12 tons is constructed entirely of wrought-iron plates, and may be worked by steam.

M. Vernay, Paris, exhibited a *portable weighing elevator*, for warehouses, cellars, or caves, by means of which the goods may be raised, weighed, carried, and deposited at any part of the floor. It is reported that two men can work and move an elevator capable of hoisting from 15 to 20 tons. There is a main column upon which the carrying-platform slides, guided by sliding brackets.

M. F. Winand, Liège, exhibited a *double-safety lifting-jack*, fitted with toothed gearing moved by a worm. The worm locks the jack in any position, and the load can only be lowered by actually reversing the worm by hand.

CHAPTER III.

STEAM PILE-DRIVER.

Mr. Nasmyth was the first who applied steam-power to the pile-driver. In 1842 it occurred to him that the principle of his direct-action steam-hammer might be applied to supersede the old tedious and imperfect mode of driving piles. Accordingly he patented this application of the principle, and it was put into practical

FIG. 416.



STEAM PILE-DRIVER, by Messrs. Sissons & White, Hull.

operation in 1845, since which time it has been successfully employed in the construction of some of the most gigantic works in Europe, America, and Africa.

Messrs. Sissons & White, Hull, exhibited a *steam pile-driver*, which, with the boiler on a separate carriage, is traversed upon a line of rails. The base of the pile-driver frame is in two thicknesses, the upper one of which is capable of revolving like a turntable upon the lower, and thus the machine may be faced round to any of the four sides. By means of a steam-winch at the base an endless chain is kept in continuous motion vertically; the ram is engaged with the chain by a bolt shot into one of the links, and is instantly lifted. The bolt is shot by means of an eccentric cam within the ram, turned by a lever and rope pulled by hand from below. When the ram is raised to the full height required, it is released by a striking-off staple on the outside of the leaders, which, striking the other end of the lever, reverses the cam and withdraws the bolt. The total weight of the driver and boiler is 6 tons, including the ram and the mountings, which weigh 22 cwt. There is one steam-cylinder to work the winch, 7 inches in diameter and 9 inches stroke. The chain usually travels at the rate of one foot per second, and the ram usually falls about ten times per minute, with a five-foot lift. The boiler is usually worked at 45 lb. pressure per square inch. Four men are required to work the pile-driver, with a consumption of 4 cwt. of coal per day. The machine is 36 feet high, and is capable of pitching a pile 30 feet long on level ground (fig. 416).

CHAPTER IV.

DRIVING-BELTS.

Driving-belts, or bands, for driving machinery, were exhibited in considerable variety,—of leather, india-rubber, and other substances.

The North British Rubber Company, Edinburgh, exhibited *india-rubber belting* in various widths. This belting consists of a number of plies of cotton fabric cemented together by india-rubber, and is said to possess the advantages of durability and superior adhesion as compared with leather. The machinery in motion in the Western Annex was driven by india-rubber belts supplied by the exhibitors, which worked in a satisfactory manner.

Messrs. G. Spill & Co., London, exhibited, in Class IV., *machinery belting*, manufactured from flax-yarn, saturated with a compound substance said to be incapable of decomposition. The following results of the tests to prove the tensile strength of this belting in the chain-cable testing

machine at Rotherhithe, appear to show that it is much stronger than leather belting:—

Belting.	Width.	Tensile Strength.	Tensile Strength per Inch Wide.
	Inches.	lb.	lb.
No. 1	5	6,272	1,254
No. 2	5	7,448	1,489
No. 3	10	16,632	1,663
" Stout leather } band of good } quality" }	4	2,100	525

Messrs. Nobes & Hunter, London, exhibited *compound leather belts*, manufactured of a strong hempen web sewed between two plies of leather.

Messrs. Bryant & Cogan, Bristol, exhibited *edge-laid leather bands*, consisting of thin strips of leather laid side by side, breaking joint, and united into one band of the requisite width. It is considered that by the mode of working the strap on the edge of the leather instead of on the face, the risk of cracking and breaking the grain of the material is avoided; whilst edge-laid bands may be used more slackly than ordinary bands, as the edge surface "hugs" the drum or pulley more than the face.

Messrs. C. J. Edwards & Son, London, exhibited *flat leather driving-bands*, put together with cemented joints no thicker than the other portions of the band. Also, *round leather bands*, from $\frac{1}{8}$ to 1 inch in diameter, either twisted or solid.

Mr. C. A. Preller, London, exhibited *untanned leather belts*. The fibres of tanned leather, he contends, are weakened by the ordinary artificial means used in swelling the hides, which produce heavier and thicker, but spongy leather. Mr. Preller's leather is twice stretched, and is of greater density, as it contracts, in drying, to the original thickness of the hide; and from the results of experiments made at Woolwich Dock-yard, to which he refers, it is said to have been ascertained that his leather is at least 50 per cent. stronger than tanned leather.

Mr. W. Potier, London, exhibited *gut wheel-bands*, also bands of twisted leather.

A few other exhibitors showed leather bands of the ordinary kind, which do not call for special notice.

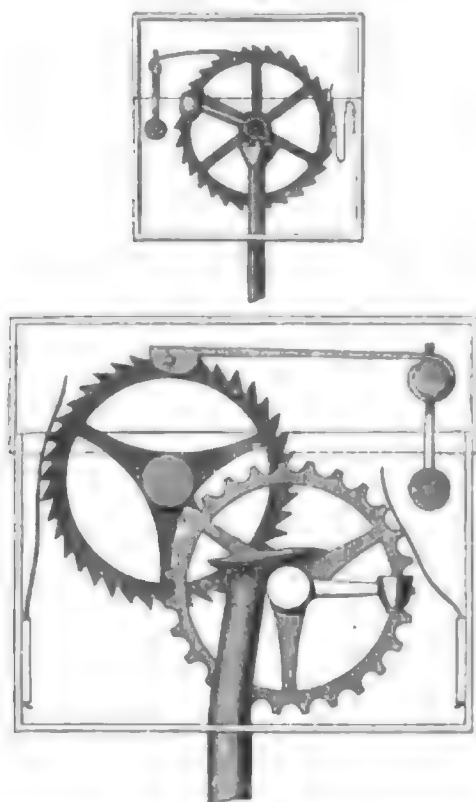
CHAPTER V.

LUBRICATORS, ETC.

Messrs. Gwynne & Co., London, exhibited *Swan's self-acting lubricator*, for shaft-bearings of every kind. It was shown in operation upon the bearings of Messrs. Gwynne & Co.'s engines, and worked effectively. By means of a

slight pendulous motion, or a rocking motion derived, say, from a small excentric on the shaft, motion is given to a simple train of gearing within the oil-box, by which a small scoop or ladle is caused to revolve slowly upon an axle, and to dip into the oil at each descent, and discharge the supply into a tube, through which the oil is conducted to the bearing. By means of a set-screw the quantity of oil to be lifted may be regulated with exactness. The toothed wheels are steadied by friction-springs bearing upon the

FIGS. 417.

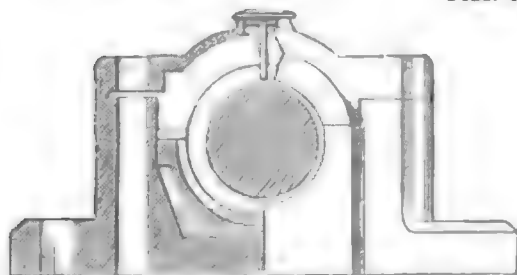


SWAY'S SELF-ACTING LUBRICATOR, by Messrs. Gwynne & Co., London.

circumference. For high-speed bearings, the speed is reduced by intermediate gearing within the box (figs. 417).

Messrs. Wren & Hopkinson, Manchester, exhibited *Mohler's self-lubricating pedestal*. The journal working in the pedestal has a central collar on the middle, which revolves in a reser-

FIGS. 418.



MOHLER'S SELF-LUBRICATING PEDESTAL, by Messrs. Wren & Hopkinson, Manchester.

voir of oil cast in the lower step, and carries up a continuous supply of oil, which lubricates the whole surface of the journal. The surplus oil runs off at the ends of the journal into receivers formed in the plummer-block, which are in com-

munication beneath the step with the central reservoir. Thus the oil is kept continually in circulation over the journal without waste (figs. 418).

Messrs. B. Hick & Son, Bolton, exhibited *Hick's self-lubricating pedestal*, on the shafting which was erected for working the machinery in motion in the Western Annex. Two reservoirs for oil are formed in the lower part of the pedestal, one at each end of the step. An endless chain hung loosely on the shaft at one end of the bearing revolves with it, and dipping into the oil lifts it in sufficient quantity to lubricate the bearing.

In Kohler's and in Hick's systems of self-lubrication, the supply of oil must be exchanged and renewed from time to time, and it must be gradually deteriorated in quality so long as it remains there. In Swan's lubricator, on the contrary, the oil is always freshly applied, so long as the supply lasts, as it does not circulate, like the others; and the rate of supply can be regulated to the utmost degree of nicety, and adapted to the requirements of a proper lubrication.

Mr. Joseph White, London, exhibited an *oil-feeder*, or oil-can, fitted with a spring-lever valve within the chamber, to close the spout, so that oil could only be allowed to pass through the spout at the will of the holder, by pressing the thumb upon a stud.

CHAPTER VI.

MEASURING INSTRUMENTS.

Mr. J. Richmond, London, exhibited an *engine-counter*, in which the number of strokes made by the engine can be read off at one view without calculation. The leading, or unit hand, traverses the entire circumference of the large dial, and the hands of the three small dials, Nos. 2, 3, and 4, all revolve in the same direction. The first motion is given by a sliding bar and fixed spring, instead of a double pallet, so that it is impossible that the first wheel can be

thrown more than one tooth by one stroke of the engine. No skip wheels are employed, and the hands are all moved by a train of wheels and pinions, so that the motion is regular and progressive. The arrangement is very simple:

—No. 1, or the large circle dial, contains 100 divisions, and the large hand traverses one division at each beat or stroke. No. 2 dial also contains 100 divisions, each one of which is equivalent to one entire revolution of No. 1 hand, thus enregister-

ing 10,000. No. 3 dial is divided in the same manner, enregistering 100,000; and No. 4 dial, also divided into 100 parts, enregisters 1,000,000. Thus any amount can be read off without any possibility of error. The only action requisite to work the counter, is a reciprocating motion of about half an inch.

Mr. J. Adcock, London, exhibited a *distance-indicator* for wheel-carriages. A pin in the nave of one of the wheels touches a pall fixed to the axle, which, by moving a piston in a cylinder, compresses the air in an india-rubber tube, by which an elastic bag is distended in connection with a spring-lever which works a train of wheels for registering the number of revolutions.

Messrs. Woodcock & Lee, London, exhibited a *machine for measuring cloth*, in which the cloth is passed between a cylinder and a roller under sufficient pressure. The counter is connected with the axle of the cylinder.

CHAPTER VII.

DIVING APPARATUS.

Diving apparatus, though placed in Class 10, as a civil engineering contrivance, deserves a short notice in connection with the machinery exhibited.

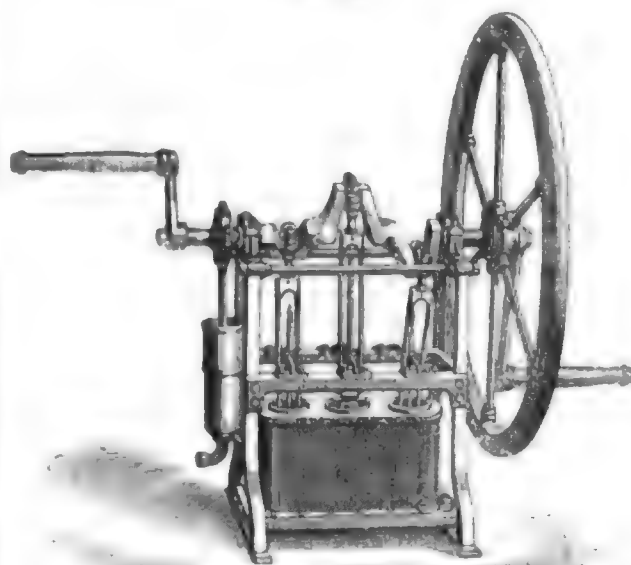
With regard to finish, one of the diving apparatus exhibited by Messrs. Heinke, London, was overdone. Iron work intended for exposure to a saline atmosphere ought to have all the exposed parts protected; but in this one the iron work was highly burnished: even the rod by which the diver feels his way among mud and stones was highly polished.

Mr. S. Barnett, London, exhibited his apparatus as usually constructed.

There were considerable differences in the construction of the pumps and helmets. The atmospheric supply-pump of the French makers wanted the solidity of the English-made pumps; and the two barrels with their toothed gearing being placed outside, is objectionable, as it is very likely to entangle the dress of the man turning the wheel. The helmet appeared similar to the others, but the weights were too light. Mr. A. Siebe did not profess to have made any alterations since 1851; but his apparatus was good and substantial. Messrs. Heinke exhibited a set of pumps without a water-cistern, which is necessary to keep the barrels cool while working. This was a great omission for the sake of a small economy in construction. Mr. Barnett and Mr. Siebe's pumps were both fitted with copper cooling-cisterns (fig. 419). Mr. Barnett claims the introduction of the dial-indicator, which is placed on the top, and consequently in view of the men working the pumps, with the cover either open or shut; but in Mr. Siebe's and

Messrs. Heinke's apparatus, the dial was fixed at the bottom, and could only be seen by the man at the pump by his leaving the handle and stooping,—thus rendering it useless. Mr. Barnett's air-pumps were fitted with condensing boxes or chambers, which serve the important purpose of

FIG. 419.



AIR-PUMP FOR DIVING APPARATUS, by Mr. A. Siebe, London.

equalising the pressure of the air, and continuing the supply for some time after the pumps have ceased working.

The helmet is even of greater importance than the air-pump. All the helmets exhibited showed the jointed neck-screw, an improvement of Mr. Siebe's, which gives instant relief by enabling the attendant to take the helmet off rapidly. In Mr. Barnett's helmet the arrangement of the front eye prevents its ever sticking; it is fitted with a vulcanized ring and joint, the advantage of which is well known to divers, as the leather joint often swells under water, and prevents its being unscrewed. In Mr. Barnett's and Messrs. Heinke's helmets, the method of enabling the diver to raise himself without assistance from above, was by stopping the air-valve and inflating the dress. For this purpose Messrs. Heinke apply an adjusting valve in front, which is both objectionable and dangerous, inasmuch as the discharged air bubbles up before the diver's face, and obstructs his vision. The danger consists in its being an adjusting valve under the control of the diver, to open or shut as he pleases. Persons unaccustomed to diving are generally affected with giddiness, when they are liable to turn the valve wrong. In such an event the giddiness is increased, and may end fatally; but with the valve shown by Mr. Barnett, while it possesses all that is required to enable the diver to raise himself without the aid of his attendant, in case of illness it immediately rights itself. Some divers assert, and with some reason, that the discharge-valve ought never to be under the control of the diver. A person once raised him-

self up under a ship's bottom and bumped his helmet against it. With a little practice, however, such an occurrence may always be avoided. With the means of raising himself a few feet,

FIG. 420.



DIVING HELMET & DRESS, and view of submarine operations; by Mr. S. Barnett, London.

the diver will often save the time and trouble of having the boat and ladder brought direct over the spot at which he is working (figs. 420, 421).

FIG. 421.



DIVING HELMET AND DRESS, by Mr. A. Siebe, London.

M. Cabirol, Paris, exhibited a submarine lamp on the same principle as one invented in England for nocturnal fishing. The lamp is seldom required, as in daytime it is not wanted, and by night, if the water is turbid, it is useless.

CHAPTER VIII.

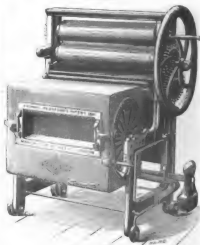
WASHING AND MANGLING MACHINES.

The process of washing linen consists in the intimate agitation together of an alkaline solution with the fabric, for the separation and precipitation of the dirt and grease. In washing linen by machinery, therefore, there must be such an amount of movement from the machine as will keep up a constant change of the solution in contact with the linen, allowing each particle of the solution to take up its equivalent of dirt, till all the dirt is separated. The agitation necessary for this purpose causes the clothes in most machines to be continually moving or sliding one piece over another, analogously to hand-washing; and that machine is the best which gives the largest amount of change in the solution with the least labour, liability to derangement, or damage to the articles to be washed. It will be convenient to divide the machines into three classes—viz., oscillating, pressing and rubbing, and rotary or dash-wheel machines.

1. *Oscillating Washing-Machines.*—In this class there were three exhibitors,—Mr. T. Bradford, Manchester; Messrs. Hornsby & Sons, Grantham; and Mr. E. Weir, London.

Mr. Bradford's machine consists of a box nearly square, which is rocked upon an axis at

FIG. 422.



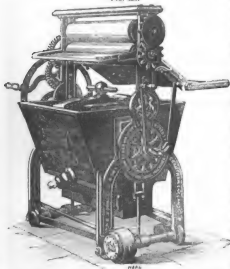
OSCILLATING WASHING MACHINE, by Mr. Thomas Bradford, Manchester.

each end, and vibrates to the extent of about two-thirds of a revolution. The box is formed inside with ribs about $1\frac{1}{2}$ inches high, placed diagonally, and intended to prevent the clothes from slipping at once from one side of the

machine to the other. Motion is given directly by hand from one handle, and the box is violently reversed by means of stops fixed upon it, which, at the end of each vibration, strike against and are reversed by the frame, so causing the clothes and water to be jerked to the other side. The square form of this box, and the small distance of the sides from the centre, render inconsiderable the motion in the clothes, particularly if there are many of them. This kind of motion does not appear to cause the clothes to interchange their positions with one another; the whole weight of the clothes and the water has to be lifted at each stroke by the operator (fig. 422).

Messrs. Hornsby & Sons' machine consists of a wedge-shaped box, hanging on gudgeons at the ends, and having a number of ribs at the bottom. The box is balanced by a weighted compensation-box attached to the bottom of it. The motion is communicated by two handles for alternate action, and the box is oscillated so far as to bring the lid into a perfectly upright position. Thus the clothes are treated with a

FIG. 423.



OSCILLATING WASHING-MACHINE, by Messrs. Hornsby & Sons, Grimsby.

considerable jerk and range of motion, facilitated by the form of the box. The box is a closed vessel, and the water and the clothes have to be lifted at each reciprocation (fig. 423).

Mr. Weir's machine, made by Mr. Summerscales, is similar to Mr. Bradford's, but it has a box of more than double the length, and the motion given to the clothes is greater. The inside is ribbed on the sides and the bottom, and the latter is formed like an obtuse W, to

catch the clothes in the middle, and give them a turn. It is a closed vessel, and the weight of the water and clothes requires to be lifted at each oscillation.

2. Pressing or Rubbing Machines.—The exhibitors in this class were Mr. Bradford, Messrs. Briggs & Starkey, Leeds; Mr. Williamson, London; and Mr. Muggridge, London.

Mr. Bradford exhibited two machines of totally different actions; the one for pressing, the other for rubbing. The first consists of a pyramidally-shaped box, hung for swinging. Two spring ribbed boards, nearly fitting the box, are suspended within it by framework; the ends of the box also are ribbed. The clothes are placed on either side of the framework, and the box is oscillated, pendulum fashion, to and fro, pressing the linen against the yielding press-board, which is so shaped as to cause the clothes to partially turn at each oscillation. This machine is an avowed modification of Mr. Williamson's.

Mr. Williamson's machine consists of a stationary square box, with a presser swinging from two standards. The press-boards, which are portions of the presser, are shaped so as to cause the clothes to partially turn at each stroke. The sides of the box are on springs, which yield to the presser, and recoil when it is withdrawn, throwing off the clothes at the same time. The motion is given either by a simple lever or by crank motion.

It is fair to remark of the last two machines—Mr. Bradford's and Mr. Williamson's—that they are both derived from a very old and well-approved machine, called the dolly machine, made by Messrs. Briggs & Starkey, Messrs. W. I. Pearson & Co. (Leeds), and Messrs. Summerscales & Son (Keighley), and many other makers. This machine is said to have been in use in Yorkshire, its birthplace, for upwards of seventy years. Its action consists in pressing the clothes against the sides of the box, when the angles of the sides are inclined inwards. Thus the clothes, when the presser or dolly is removed, are caused to fall, so as to be taken the reverse way at the next stroke of the presser. In Mr. Williamson's machine, there is substituted for this form of box a spring-board with a quadrant-shaped dolly, the only advantage of which appears to be that in driving by a crank there is something to yield in the event of an excess of clothes. In Mr. Bradford's machine, on the contrary, the dolly-frame is stationary, whilst the clothes and the water, as well as the box, are moved; and though the action of Mr. Bradford's machine is probably the more efficient, yet there is a considerable amount of labour required in pushing and pulling a heavy box and its contents backwards and forwards. The chief objection to this class of machines is, that they are necessarily open at the top, either wholly or partially, thus losing the advantage of washing in water kept as hot as it can be; and there is also the escape of steam and effluvia.

They, like their ancestor the dolly, are well adapted for washing coarse fabrics, and they are cheap machines; but all washing-machines having any working parts moving in contact with the clothes are likely to tear fine things, as muslins, fine under-clothing, &c., jamming them between the dolly and the bottom or sides of the box.

Mr. Bradford exhibited a machine with a rubbing action. It consists of a wooden roller ribbed longitudinally, for about a quarter of its circumference, on two opposite sides, the intermediate portions being left plain. This roller acts on a series of rollers hung in a flat frame, which are yielding and are immersed in a trough. The clothes are fed between the frame of small rollers and the upper or partially ribbed roller, and they are held by the hand, while the ribbed roller rubs and presses the clothes against the small rollers beneath. The soap is fed from the top, and the vessel is open. This machine is adapted to wash articles requiring a considerable friction on their outer surface, as new shirts or collars; but it does not appear to be so well adapted for a general wash of large things, or of flannels. On the latter it would exert a felting action.

Messrs. Briggs & Starkey, Leeds, exhibited a machine, consisting of a trough having a circular bottom, ribbed longitudinally. A drum, consist-

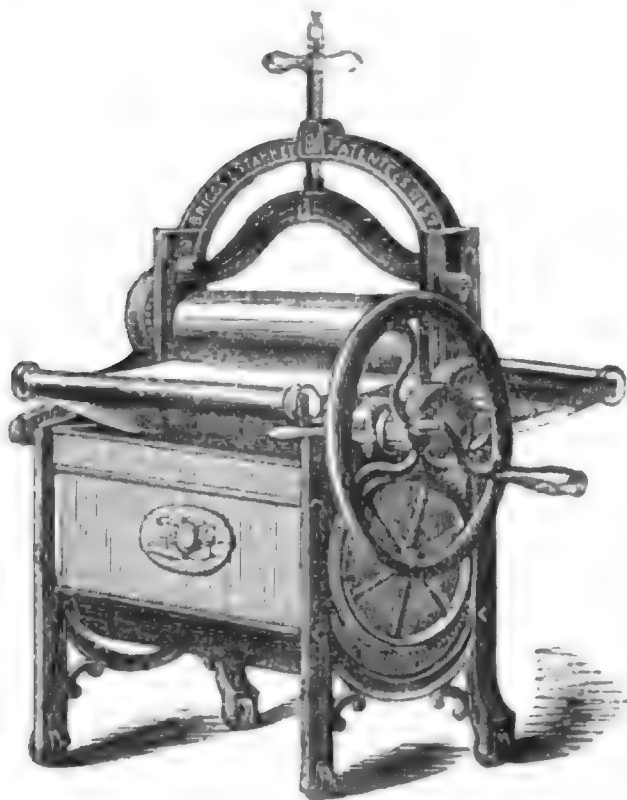
against the ribs of the box, there being a yielding pressure by means of springs. The motion is slow, and the placing in and taking out of the clothes takes time; the machine holds but few clothes, and the motion is not adapted for turning out a large quantity of work (fig. 424).

Mr. Muggridge exhibited a machine like a fulling-mill, in which the presser, hung from above, is worked backwards and forwards against the clothes in a corner at the bottom. The clothes receive a great deal of squeezing or punching; but they are not separated and turned over, which is nevertheless necessary for thoroughly cleaning dirty linen. The machine is open at the top, and shallow, and the water does not long retain its heat. The upper part of the dolly, or presser, is formed like a ridged table, on which the dirty parts of the linen are soaped before being consigned to the machine.

3. Rotary or Dash-wheel Machines.—Machines of this class were exhibited by Mr. W. Hargreaves (Manchester), Mr. R. Lansdale (Manchester), Messrs. W. Pearson & Co., and Messrs. Summerscales & Son. The best judges of washing-machines—the bleach-workers,—have always preferred and used the dash-wheel. In their large wheels the materials to be washed are lifted by the internal ribs on the rim to a height of more than half the diameter, from whence they fall into a body of alkaline solution with some force. In the domestic machine, the attempts that have been made have all been directed to getting an action analogous to this by means of very small cylinders; but the difficulty has been to adapt the principle, in size and price, to the requirements of private life. This has been tried by Mr. Hargreaves, in his waterfall machine, which not only raises the linen above the centre, but the water also. The motion is necessarily slow, because with a fast motion the clothes and water would be carried centrifugally, completely round, without altering their positions. The lid by which the clothes and water are introduced revolves with the wheel, and should be made watertight.

Mr. Lansdale's machine contains a barrel, as in Mr. Hargreave's machine, to which a compound motion is communicated. It is suspended by pivots axially in a frame, which itself is hung upon transverse pivots. The first or dash motion takes place on the transverse axis, on which the barrel is turned over and over by means of a handle and gearing; by the second motion, with differential gearing, the barrel or tub is turned on its axis for the purpose of changing the side of the tub in contact with the linen. The inside is fitted with knobs which help to hold the clothes in position, and, probably, cause them to be carried further round before being disengaged and thrown down. The second motion in this machine is probably not worth very much. The first motion is necessarily slow, for the same reasons as in Mr. Hargreave's machine; the lid is required to be watertight, and the water and

FIG. 424.



RUBBING WASHING-MACHINE, by Messrs. Briggs & Starkey, Leeds.

ing of two circular discs, with two bars, round which the clothes are loosely placed, is hung within the trough, and is turned each way alternately, making a few revolutions at a time, being reversed by hand. The clothes are rubbed

clothes are required to be lifted by the driving-power.

Messrs. Pearson & Co's machine possesses still more of the character of the true dash-wheel, but from its very slow rotating speed, only half that of the handle, and its very small diameter, it is open to the objection of want of rapid performance. It consists simply of a sparred cylinder revolving in a trough. The clothes are placed in the cylinder, and the machine only raises the clothes and the water they contain, and does not impose on the operator the task of raising the whole of the loose water in addition.

Messrs Summerscales & Son's dash-wheel machine has a sparred cylinder reciprocating on its axis within a trough, differing from all the others in having a rocking motion for the dash-wheel, which, in the first place, admits of the wheel being driven at a much higher velocity without

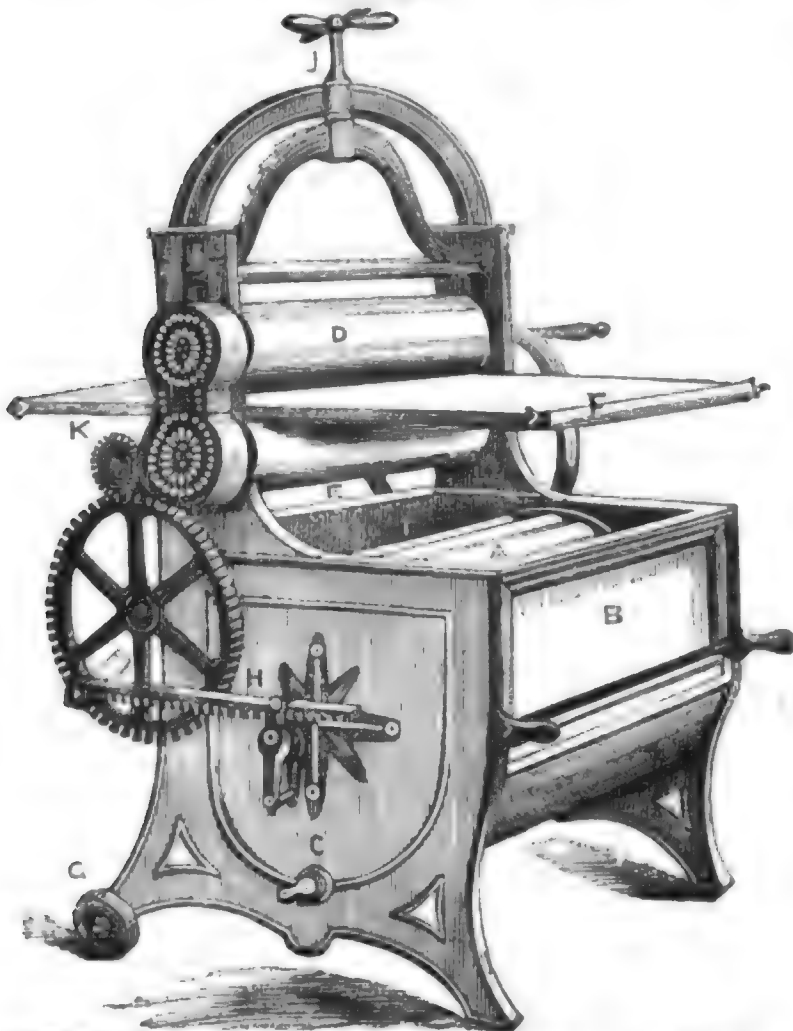
of the circumference of the barrel, are fitted with framed spars, on one side of which three brushes are fixed, which can be turned inwards to work upon coarse and dirty articles, or outwards where the articles would be liable to injury from their use. This machine appears the most nearly to fulfil the duties of a large dash-wheel, in giving, by its quick reversing action, a jerk or dash to the clothes equivalent to the greater height from which they would fall in a large cylinder—an equivalent which is not otherwise got in a small cylinder. The brushes also assist in carrying round and in cleaning the clothes. This machine does not lift the whole of the water, and it has a closed trough, preventing loss of heat and escape of effluvia (fig. 425).

The wringing process is the same in all washing-machines,—passing the wet clothes between a pair of wooden rollers, of which the upper one is covered, when necessary, with flannel, to protect shirt-buttons. The differences consist only in the modes in which the pressure is obtained. Mr. Bradford, Mr. Lansdale, and Mr. Williamson apply weights and levers for the purpose; Mr. Pearson has spiral springs; Messrs. Briggs & Starkey, Mr. Hargreaves, Mr. Summerscales, and Mr. Weir use elliptical springs; and Messrs. Hornsby have wooden springs. Of the two systems of obtaining pressure for small rollers similar to those in use in these machines, levers and weights have the objection of giving only the same pressure on a heavy quilt that they would on a cambric handkerchief; and when, as is usually the case, the levers are horizontal when the rollers are close together, the passing of a thick article between them causes the weight to rise in a small arc of a circle, and reduces the leverage, and consequently the pressure. The weights, too, are liable, after anything very thick has been passed through and withdrawn from the rollers, to come down with a jerk upon the floor. Being placed on the outside of the machine, they add to the room taken up, as well as to the cost of transit. Within limits so narrow as to be valueless, they are also incapable of adjustment. Mr. Pearson's spiral springs are of a form liable to breakage from jerks. Messrs. Hornsby's wood spring has but little

play, and is liable to derangement from a too damp or a too dry atmosphere.

The other machines are all fitted with the elliptical spring, by suitably adjusting which a thin article may be subjected only to the weight of the top roller, while, as the thickness of the articles increases, so also does the pressure.

FIG. 425.



DASH-WHEEL WASHING-MACHINE, by Messrs. Summerscales & Son, Keighley. A, drum inside of tub; B, tub; D, steam-rollers, strongly hooped with iron, and capped with brass hoops; E, drip-board; F, mangling-cloth; H, oscillating motion, by reciprocating rack and pinion, for the dash-wheel.

causing the clothes to adhere by centrifugal force to the inside of the barrel unchanged in position. The barrel only makes one complete revolution before being reversed, when the linen is by the change of motion thrown down and driven again through the water. The openings, of which there are two for the whole length, on opposite sides

There is a regulating screw for adapting the spring to very thick articles, but it is rarely used in practice, the spring having been found to adapt itself by its natural play to articles of various thickness.

Messrs. Briggs & Starkey's machine is fitted with an endless cloth for mangling, of which the ends revolve upon two small rollers fixed in a frame, hinged and removable out of the way while wringing. At each end of the machine one thickness of the cloth passes through the rollers, carrying the clothes to be mangled. Mr. Summerscales has a single cloth strained on an iron frame, which is only put on to the machine for mangling. The cloth carrying the clothes passes through the rollers. The advantage of these two mangles is, that many small articles, as napkins, can be passed through the rollers at once, instead of singly, as in the others.

CHAPTER IX.

SUNDRY APPARATUS.

Mr. T. S. Truss, London, exhibited an *elastic pipe-joint* for gas and water mains, to provide for the expansion and contraction of the metal, deflection, and easy removal and insertion of pipes without cutting them. The pipes are cast with a small head on each end, upon which a ring of elastic packing is placed when the pipes are brought near together. An iron clasp, in three segments, and formed with two interior grooves to embrace the heads on the pipes, is placed around the packing, and screwed up tight

FIG. 420.



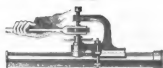
ELASTIC JOINTS for Gas and Water Pipes, by Mr. T. S. Truss, London.

upon it, to make the joint. According to the width of the band and the liberty in the grooves, the joint is more or less flexible, resembling in its action a ball-and-socket joint. The packing used for gas and cold-water pipes consists of prepared woollen felt; for hot-water pipes it consists of india-rubber. The joints have been made upon pipes of from 2 inches to 4 feet in diameter, and are said to have been satisfactorily tested to a pressure of 1,000 feet head of water (figs. 426).

Messrs. Bryan Donkin & Co., London, exhibited *Upward's drilling apparatus*, which furnishes the means of safely drilling holes in

gas-mains when laying service-pipes, as the hole is both drilled and tapped without allowing an escape of gas (fig. 427).

FIG. 427.



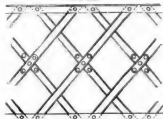
UPWARD'S DRILLING APPARATUS, by Messrs. Bryan Donkin & Co., London.

FIG. 428.



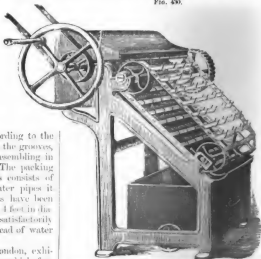
BELT-SHIFTER, by Mr. John C. Gore, U.S.

FIG. 429.



BASKET BRIDGE-WORK, by Messrs. T. Dunn & Co., Manchester.

FIG. 430.



MAGNET-MACHINE, for separating iron borings and slugs from brass borings, by Messrs. Routledge & Osmannery, Manchester.

Mr. John C. Gore, Massachusetts, exhibited a *belt-shifter*, designed for preventing the accidental shifting of belts, in ordinary circumstances. The guide is worked by a cord and lever, and locked automatically in its proper position by a detent, controlled by springs. The mechanism is so arranged that when the belt is to be shifted, the detent is lifted out of contact, the slide is moved, and the detent replaced (fig. 428).

Messrs. T. Dunn & Co., Manchester, exhibited a piece of *basket bridge-work*, which may be of wrought-iron lattice or steel lattice (fig. 429).

Messrs. Routledge & Ommanney, Manchester, exhibited a *magnet machine*, for separating iron borings and filings from brass borings by means of a number of horse-shoe magnets on an endless revolving frame, consisting of two chains carrying cross battens to carry the magnets. The magnets are passed through the borings in different tracks, so that every particle of iron may finally be separated from the brass. As the magnets

pass over the upper roller on which the chain revolves, the particles of iron adhering to them are brushed off into a box by a revolving brush. The larger size of machine is capable of clearing 81 cwt. of borings in ten hours (fig. 430).

Amongst the magneto-electric machines, one was exhibited by Mr. E. C. Shepard, a notice of which probably would have found a more fitting place beside that of Professor Holmes's magneto-electric light machine. Mr. Shepard's machine was originally intended for the production of illuminating gas by the decomposition of water. The arrangement of magnets and coils is very similar to that used by Mr. Holmes in his machine; and it is said that Mr. Holmes's invention of the electric light was the result of an endeavour to discover a profitable use for Mr. Shepard's machine, when it was found that it could not be worked at a profit as a gas-generator.



THE WESTERN ANNEX.

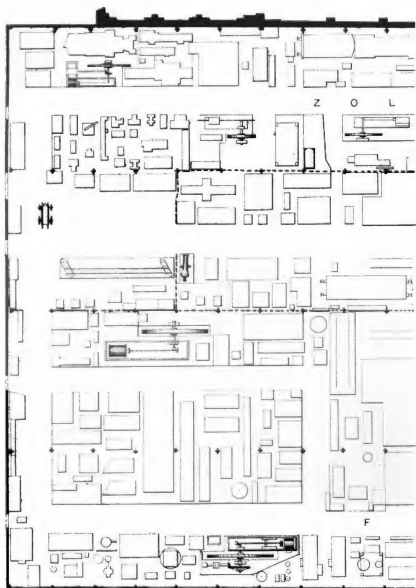
PLAN OF THE WESTERN ANNEX.

PLATE XXXIX.

REFERENCES TO THE ENGLISH DEPARTMENT.

1. Mandslay, Sons, & Field.
2. John Penn & Sons.
3. Humphrys & Tennant.
4. J. P. Ashton.
5. Laird Brothers.
6. Tod & McGregor.
7. Merryweather & Son.
8. Sundry Models.
9. London & North-Western Railway Company.
10. Richardson & Sons.
11. J. & G. Rennie.
12. John Key.
13. R. Kitchin.
14. Ravenhill, Salkeld, & Co.
15. R. Morrison & Co.
16. E. E. Allen.
17. Joseph Whitworth & Co.
18. Sharp, Stewart, & Co.
19. Wm. Muir & Co.
20. John Hetherington & Sons.
21. G. & A. Harvey.
22. A. Shanks & Co.
23. Peter Fairbairn & Co.
24. Macle & March.
25. James Nasmyth & Co.
26. J. S. Hulac.
27. Holtzapffel & Co.
28. Shepherd, Hill, & Co.
29. Beyer, Peacock, & Co.
30. Smith, Beacock, & Tennant.
31. Greenwood & Batley.
32. T. Robinson & Son.
33. W. Cunishee.
34. Waterloo & Sons.
35. J. Ross.
36. Weston & Horner.
37. J. & T. Young.
38. Forrest & Barr.
39. E. Conroy, U. S.
40. W. Geaves.
41. R. H. Thompson.
42. Cox & Son.
43. Powis, James, & Co.
44. Worasam & Co.
45. J. McDowall & Sons.
46. J. Ferrabee & Co.
47. — Clunes.
48. Johnson & Atkinson.
49. W. H. Mitchell.
50. Petter & Galpin.
51. Bryan Donkin & Co.
52. George Bertram.
53. J. & R. M. Wood.
54. J. Smith & Son.
55. T. J. Marshall.
56. J. Sinclair.
57. Sharp, Stuart, & Co.
58. C. W. Harrison.
59. T. M. Tennant & Co.
60. Ransomes & Sims.
61. J. & W. Stuart.
62. Emery Brothers (U.S.)
63. Walker & Hacking.
64. Wren & Hopkinson.
65. J. Hetherington & Sons.
66. Platt Brothers & Co.
67. Dobson & Barlow.
68. John Mason.
69. W. Higgins & Sons.
70. Routledge & Ommaney.
71. Sandys, Vivian, & Co.
72. Martin Samuelson, & Co.
73. Mirrlees & Tait.
74. Fawcett, Preston, & Co.
75. G. Forrester & Co.
76. J. C. Wilson & Co.
77. W. & A. McOnie.
78. Henry Clayton & Co.
79. W. Wilson.
80. Doulton & Co.
81. J. D. Brunton.
82. B. Fowler & Co.
83. Peter Effertz.
84. R. Wood & Sons.
85. Easton, Amos, & Sons.
86. W. D. Andrews (U.S.).
87. R. Legg.
88. Whitmore & Sons.
89. D. Napier & Son.
90. Manlove, Allott, & Co.
91. Ransomes & Sims.
92. Perreux & Co.
93. Sir W. G. Armstrong & Co.
94. North British Rubber Company.
95. S. Leoni.
96. J. Beck.
97. T. Leadbetter & Co.
98. Glen & Ross.
99. Eastwood & Sons.
100. Peel, Williams, & Peel.
101. Hayward Tyler & Co.
102. J. Tylor & Sons.
103. Warner & Sons.
104. T. Lambert & Sons.
105. Routledge & Ommaney.
106. R. A. Godwin.
107. Lee Norton.
108. Tangye Brothers & Price.
109. Lumley & Watson.
110. Patent Frictional Gear Co.
111. Thompson & Stather.
112. C. W. Siemens.
113. A. Smith.
114. Bryan Donkin & Co.
115. John Chedgley.
116. J. Rhodes.
117. Walter May & Co.
118. Richard Roberts & Co.
119. Carrett, Marshall, & Co.
120. North Moor Foundry Co.
121. Harvey & Co.
122. Knowelden & Co.
123. T. Middleton.
124. J. U. Bastier.
125. Barrett, Exall, & Andrews.
126. Williamson Brothers.
127. Lillieshall Company.
128. Bunnett & Co.
129. G. Lloyd.
130. F. O. Ward.
131. Gwynne & Co.
132. E. T. Bellhouse & Co.
133. G. Simpson.
134. A. Handyside & Co.
- 134a. B. Fleet.
135. Normandy & Co.
136. D. Siebe.
137. S. Barnett.
138. Beyer, Peacock, & Co.
139. London & North-Western Railway Company.
140. Sir W. G. Armstrong & Co.
141. Neilson & Co.
142. Sharp, Stewart, & Co.
143. George England & Co.
144. Robert Sinclair.
145. Wm. Fairbairn & Sons.
146. Chaplin & Co.
147. Manning, Wardle, & Co.
148. Neath Abbey Company.
149. E. C. Shepherd.
150. N. Grew.
151. Thomas Dunn & Co.
152. G. E. Dering.
153. W. B. Adams.
154. J. Hoy.
155. Captain P. P. Stafford.
156. Ordish & Le Feuvre.
157. J. Newall.
158. W. Hattersley.
159. W. H. Kingston.
160. — Leigh.
161. J. Davidson.
162. W. Baines & Co.
163. S. S. Bateson.
164. A. Vickers.
165. S. Moulton & Co.
166. T. Wright & Co.
167. E. Morris.
168. Bayliss, Simpson, & Jones.
169. Ieca Foundry Company.
170. P. M. Parsons.
171. G. A. Biddell.
172. W. Simons & Co.
173. Weston & Grice.
174. F. Wise.
175. Governor and Company of Copper-mines in England.
176. Robert Richardson.
177. Thomas Edington & Sons.
178. Anderston Foundry Company.
179. W. Seaton.
180. H. L. Corlett.
181. Permanent Way Company.
182. Henry Pooley & Son.
183. Stevens & Son.
184. Clayton, Shuttleworth, & Co.
185. T. W. Cowan.
186. M. Hubert (France).
187. F. H. Holmes.
188. H. C. Hurry.
189. E. B. Neill.
190. Turkish Engine.
191. Belliss & Seekings.
192. Hunt & Roakell.
193. M. Lyons.
194. Madame Sinibaldi.
195. A. Morrell.
196. D. & W. Gibbs.
197. Greek Steam Navigation Company.
198. Stothert & Pitt.
199. M. Fentum.
200. Porter, Hinde, & Porter.
201. S. De Bergue.
202. Charles De Bergue & Co.
203. Thwaites & Carbutt.
204. Robert Morrison & Co.
205. D. Cook & Co.
206. A. C. Wylie.
207. Kirkstall Forge Company.
208. Hudswell & Clarke.
209. John Imray.
210. T. W. Cowan.
211. J. Hands.
212. Joshua Buchton & Co.
213. Fox Brothers.
214. H. Garside.
215. Crawhall & Campbell.
216. Evan Leigh & Son.
217. Smith & Coventry.
218. Patent File Machine and File Manufacturing Company.
219. J. Davis.
220. W. Gadd & Son.
221. J. Glasgow.
222. J. & J. Kershaw.
223. Peto, Brassey, & Betts.
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228. Hughes & Kimber.
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231. R. Rhodes.
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235. D. & J. Greig.
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237. D. Napier & Sons.
238. E. & W. Ullmer.
239. Annable & Bench.
240. C. T. Youngman.
241. H. Goodall.
242. John Imray.
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245. Ward & Gaskell.
246. G. H. Gerish.
247. J. Dixon & Sons.
248. G. Tidcombe & Sons.
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250. George Hodgson.
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252. W. Smith & Brothers.
253. W. Dickinson & Sons.
254. Tuer & Hall.
255. C. T. Porter (U.S.).
256. J. Harrison & Sons.
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258. G. Hattersley & Son.
259. J. Whitesmith.
260. Jackson & Graham.
261. Henderson & Co.
262. Macle & March.
263. J. Haley & Sons.
264. J. Ferrabee & Co.
265. John Imray.
266. S. Lawson & Sons.
267. P. Fairbairn & Co.
268. John Imray.
269. Tuer & Hall.
270. J. Rowan & Sons.
271. J. Kerr & Co.
272. J. Perry.
273. J. Coombe & Co.
274. Barrett, Exall, & Andrews.
275. C. Parker & Sons.

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3. Humpl
4. J. P. A
5. Laird J
6. Tod &
7. Merry
8. Sunde
9. Londo
10. Railw
11. Richar
12. J. & G
13. John R
14. B. Kite
15. Raven
16. R. Mos
17. E. E. A
18. Joseph
19. Sharp
20. Wm. I
21. John I
22. G. & A
23. A. Sha
24. Peter J
25. Macle
26. James
27. J. S. I
28. Holtz
29. Sheph
30. Beyer,
31. Smith,
32. Green:
33. T. Rol
34. W. Ca
35. Wa
36. J. I
37. We
38. J. & A
39. Forr
40. E. C
41. W. G.
42. R. H
43. Cox &
44. Powis
45. Worra
46. J. M
47. J. Fe
48. — Cl
49. John
50. W. H
51. Pettes
52. Bryar
53. Georg
54. J. & b
55. J. Smi
56. T. J.
57. J. Sin
58. Sharj
59. C. W
60. T. M.
61. Ransc
62. J. & V
63. Emer
64. Walk
65. Wren
66. J. He
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68. Dobs
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